ISSN 0142-7229

electronics today

INTERNATIONAL

OCTOBER 1982 85p

BUILD SIX PROJECTS AND WIN £100 WITH OUR FREE PCB!

Arm your ZX81–Servo interface to run models or robots, programmable from the keyboard

Amplifiers typecast– MOSFET, Class-A, Magnetic and Bi-polar designs compared

Low cost message panel project: Computer controlled and stackable

STICK PCB HERE

FREE PCB WORTH OVER £1·00

...AUDIO....CO...MUSIC....RADIO....ROBOTICS...

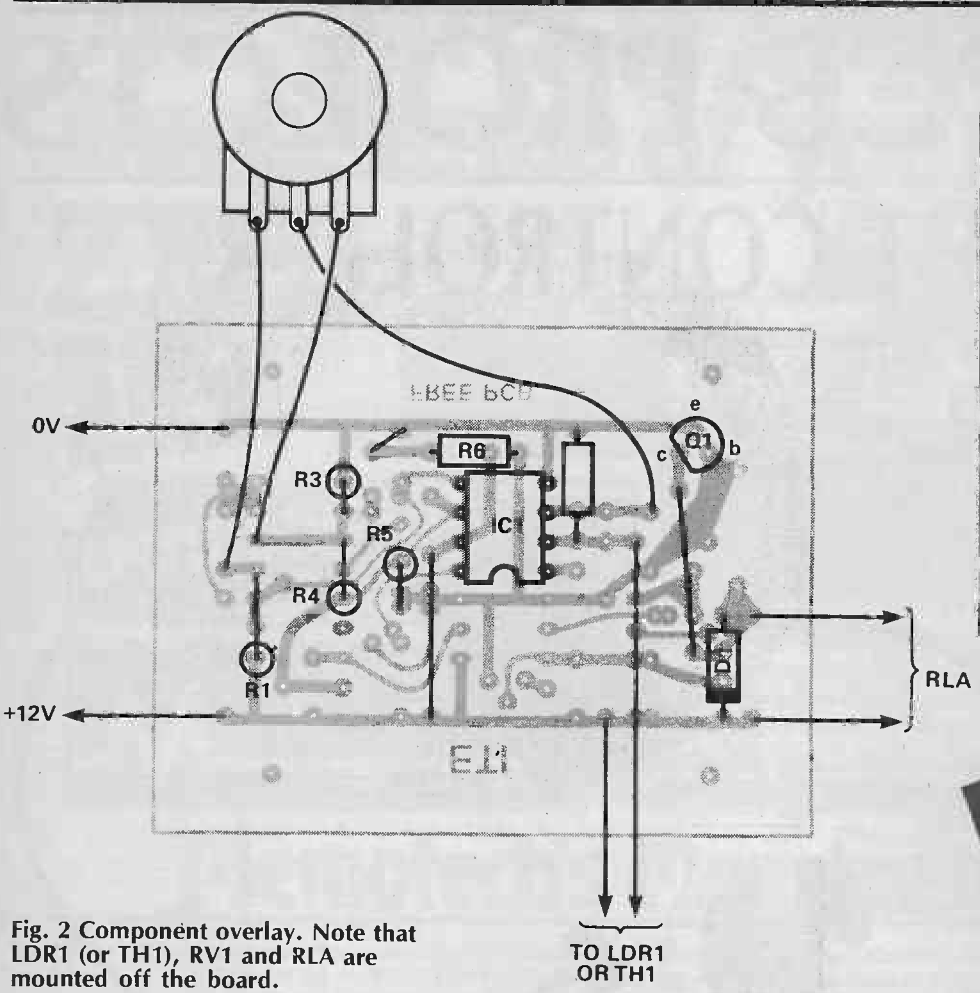
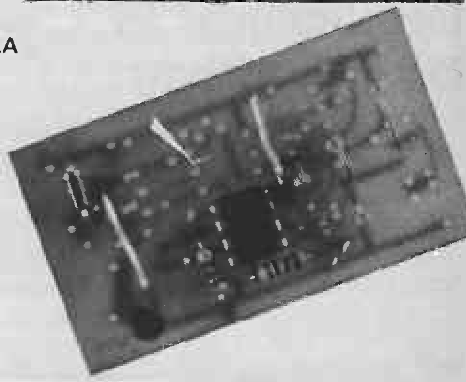


Fig. 2 Component overlay. Note that LDR1 (or TH1), RV1 and RLA are mounted off the board.

PARTS LIST

Resistors (all ¼W, 5%)	
R1,2,6	1k0
R3	100R
R4,5	10k
Potentiometer	
RV1	10k linear
Semiconductors	
IC1	741
Q1	BC184L (or any other general purpose NPN transistor)
D1	1N4001
Miscellaneous	
LDR1	ORP12
	or
TH1	thermistor — see text
RLA	12V relay, minimum coil resistance 100R; see text
PCB	



HOW IT WORKS

The only difference between the circuit used as a porch light controller and as a thermostat is the transducer used — the operation of the circuit in sensing the change of resistance of the LDR or thermistor is identical. For the LDR, the resistance increases as the light falling on the sensitive surface lessens. If you use a thermistor with a negative temperature coefficient, as we suggest for the thermostat, then its resistance increases as the temperature falls. So in both cases, the circuit should turn on the relay as the resistance of the transducer increases.

The transducer chosen is used with a 1k0 resistor to create a potential divider at the inverting (−) input of the op-amp, so that the potential seen at the input is dependent on either the light or the temperature. There is another potential divider supplying the non-inverting (+) input, but in this case the input voltage is determined solely by the position of the potentiometer slider (neglecting supply variations).

Differential op-amps have the property of amplifying the voltage difference between the inverting and non-inverting inputs. Without negative feedback, the internal DC gain of 100 dB (× 100,000) is obtained. This means that whenever the inverting input voltage is greater than the non-inverting input voltage, the output of the op-amp goes to its minimum — a volt or two above 0 V. If the non-inverting input voltage exceeds the inverting input voltage, the output rises to nearly + 12 V.

The effect of R3 and R4 is to introduce very limited positive feedback, and so hysteresis (not to be confused with hysteria, which is an effect widely found amongst ETI editorial staff). The op-amp will switch on at one light level (or temperature) and go off at a slightly higher one. This is to provide clean switching, with no flickering on and off of the controlled light or heater.

Q1 is driven via R5 and R6, and in turn drives the relay. R5 is necessary to limit the base current of the transistor; R6 prevents the minimum (off) output of the op-amp from turning Q1 on. D1 protects Q1 against any back-EMF generated by the relay coil.

Transposing the transucer (LDR1 or TH1) with R2 will have the effect of reversing the switching action of the circuit, ie the light will go off as daylight fades.

IF STRIP TESTER

You're listening to Terry Wogan when the radio goes dead; if you're one of the few people in the country who wouldn't regard this as a blessing, here's a simple little circuit to help you to find the fault. Design and development by Andy Elam.

The IF strip tester is a very useful and simple-to-build piece of test equipment. The purpose of it is to inject a signal onto an AM radio's IF strip and determine where a fault might be — the test waveform used is a 455 kHz signal modulated by 1.5kHz. The probe should be first connected to the radio's earth rail with the croc-clip; the point of the probe should be touched onto various points along the IF strip while the radio is switched on. If the section works the radio will demodulate the signal and give a 1.5kHz tone through the loudspeaker. When no signal is output the fault must lie after that point in the circuit.

Construction

A suitable probe can be constructed from an old ball-point pen case with a piece of 50R aerial cable. The refill should be removed from the pen, along with the end-cap. Strip 9″ from the end of the cable and insert this into the pen, forcing the sleeve of the cable into the end of the pen. This may be glued (if necessary) with an epoxy adhesive, eg Araldite. Then strip the screen of the cable back to the top of the pen, tin the end and insulate it with a piece of plastic sleeving. The end should be soldered to an insulated croc-clip. The inner core should be cut back to about 1cm and stripped to the end of the pen. The tip may now be tinned and gently filed away to form a point. Strip the other end, tin the cable and solder it to the board when this is completed.

The board should be constructed as shown in the component overlay. Once complete, the output may be tested with a 'scope. The faster frequency seen should have a period of approximately 2.2uS. If this is less than 2.1uS or greater than 2.3uS a 1k0 variable resistor may be connected in place of R3. Once the correct piece is obtained, the potentiometer should be removed and measured on a multimeter. The closest preferred value should then be used to replace R3.

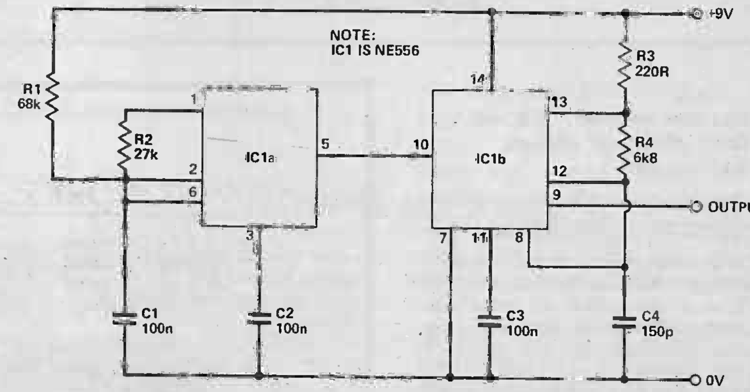


Fig. 1 Circuit diagram of the 1F strip tester.

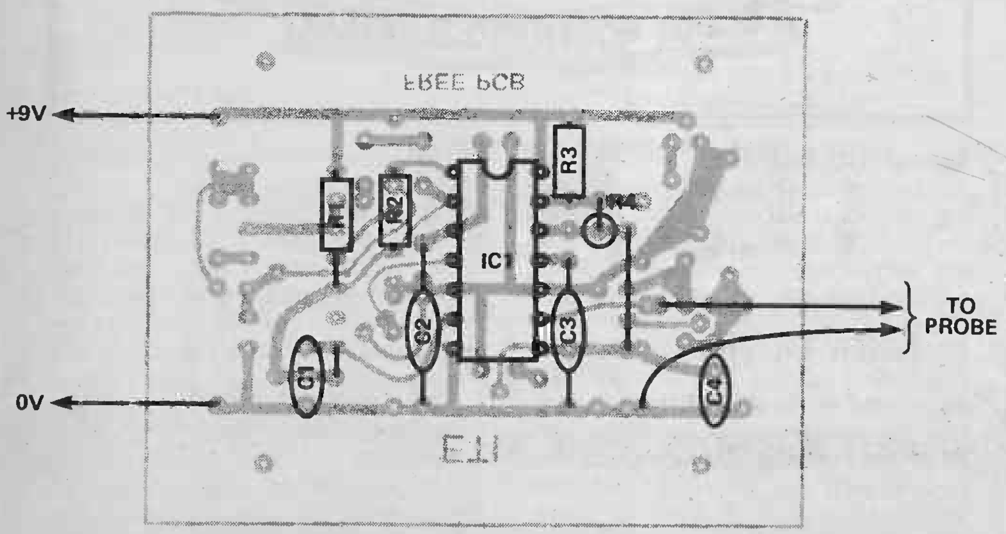


Fig. 2 Component overlay.

PARTS LIST

Resistors (all ¼W, 5%)	
R1	68k
R2	27k
R3	220R
R4	6k8
Capacitors	
C1,2,3	100n ceramic
C4	150p ceramic
Semiconductors	
IC1	NE556
Miscellaneous	
PCB; test probe (ball point pen, 1m solid inner core 50R coax cable)	

HOW IT WORKS

The circuit uses a dual 555-type timer chip, the NE556, and it's very similar in action to the doorbell circuit. The first section, built around IC1a, is a 1.5kHz square wave generator. This is set by the time constant of R1, R2 and C1. Pin 5 is the output, which is sent to the reset pin of the next astable. This section generates a rectangular (not quite square) signal, at around 455kHz modulated by the 1.5kHz square wave from IC1a.

ELECTRONIC DOORBELL

If he'd had this project instead of the bells, Quasimodo wouldn't have gone deaf; let your visitors announce themselves with a gentle warbling. Design and development by Andy Elam.

This circuit is a simple but useful device which may be used for many applications as well as the intended doorbell. No problems should be encountered with the construction of this project if the overlay diagrams are closely followed. The push-button may be a standard bell-push. However, if you use an illuminated bell-push, you'll have to use a mains-powered supply and reduce the value of R3 to around a few tens of ohms — you'll have to experiment to get a suitable value, because it will depend on the bulb in the bell-push. Should you want to change either of the frequencies the CR networks may be adjusted to suit. The frequency of oscillation of IC1 is given by:

$$\frac{1.44}{(R1+2R2) \times C1}$$

(R1 and R2 in ohms; C1 in farads).

Other variations may also be obtained with some ingenuity — try varying the signal fed to the second astable as well as the two repeat and tone frequencies.

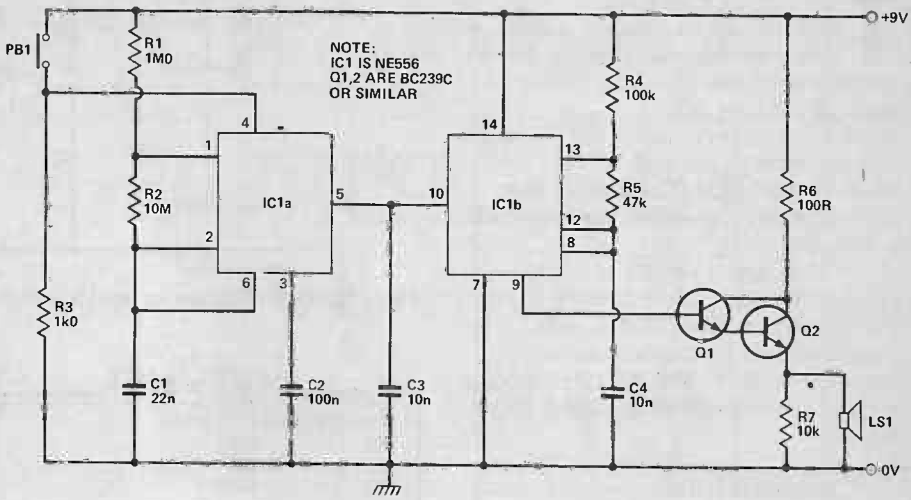
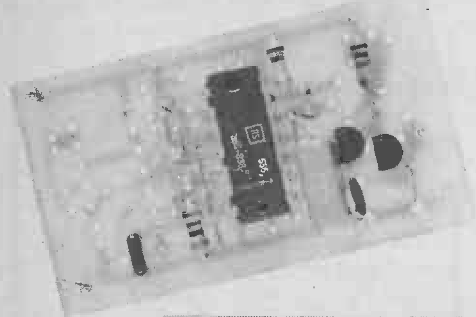


Fig. 1 Circuit diagram of doorbell.



HOW IT WORKS

The circuit functions in a similar way to the IF strip tester. A 556 is used to provide two 555-type timers, connected here as astable multivibrators with unequal on and off periods. The first of these provides the lower, modulating frequency which gives the repeat rate. The second astable gives the higher frequency, ie the tone. Thus when the push-button is pressed the tone is generated and modulated on and off at the repeating frequency.

Until PB1 is pushed to make, the reset input of IC1a is held low by R3; this ensures that the output of IC1a (pin 5) is held low, so that the reset input (pin 10) and hence the output (pin 9) of IC1b are also held low. When PB1 makes, IC1a oscillates at a frequency determined by R1, R2, and C1 — with the values shown this is about 3 Hz. IC1b will oscillate at a frequency determined by R4, R5 and C4 (about 750 Hz) only while its reset input is high, hence producing the modulated tone.

The Darlington pair, Q1 and Q2, are used to provide sufficient current to drive LS1.

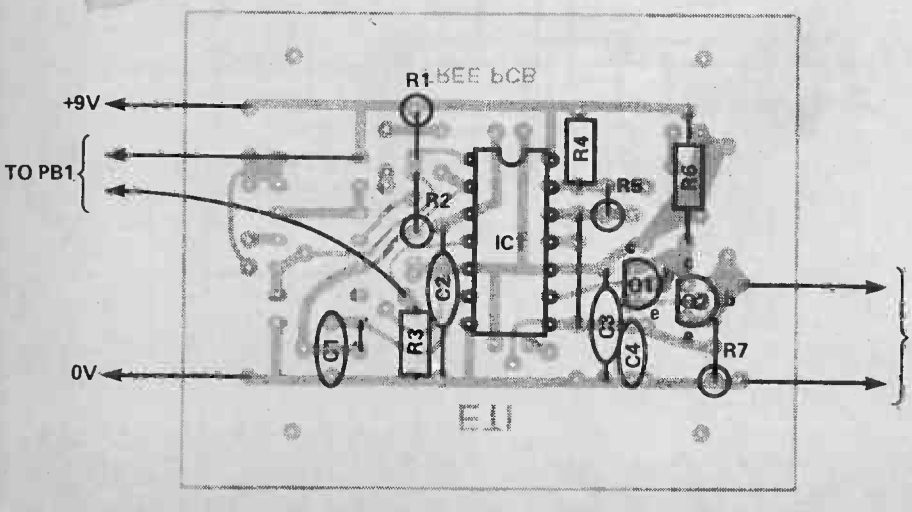


Fig. 2 Component overlay.

PARTS LIST

Resistors (all ¼W, 5%)

R1	1M0
R2	10M
R3	1k0
R4	100k
R5	47k
R6	100R
R7	10k

Capacitors

C1	22n ceramic
C2	100n ceramic
C3,4	10n ceramic

Semiconductors

IC1	NE556
Q1,2	BC239C or similar

Miscellaneous

LS1	8R miniature loudspeaker
PB1	push-to-make switch
PCB	

TOUCH SWITCH

Get a touching feeling with our CMOS touch switch. Design and development by Andy Elam.

This circuit uses CMOS technology to provide a time delay switch, suitable for use in situations where you don't want to leave a light on all night. This is very useful for those of us fortunate (?) enough to be blessed with kids. The circuit can control mains-powered lighting with a suitable relay.

A time latch switch is built around a micropower CMOS IC. In the quiescent state, this IC will consume less than one microamp from the supply. The IC employed is a quad two-input NAND gate, the 4011.

Construction

This is very straightforward; the touch pads may be any type of metal connections which will not corrode or oxidise, mounted on a good insulator such as a plastic sheet. Two screw heads could be used. If the time constant is too short a larger capacitor may be used, or a smaller capacitor to get a shorter time constant. The board is small enough to stick to the relay with some double-sided sticky pads if required.

HOW IT WORKS

When the circuit is waiting for a touch the input to the first gate, IC1a, is pulled high via the 10M resistor. So the output of IC1a is low, the input to the Darlington pair is low and the transistors do not conduct or draw any significant current.

When the contacts are bridged by the relatively low resistance of the skin, the input of IC1a is pulled low, and this leads to all the other gates switching their states. Thus, the negative plate of C1 rises to around + 12 V. After skin contact is removed, the first gate will resume its quiescent state, with input high and output low. R1 gradually recharges C1, so that the negative plate voltage drops (the input impedance of IC1b can be neglected because it's very high). With a 22uF and 1M0 resistor combination approximately 8 seconds elapses before the input to IC1b goes low enough for the Darlington pair to be turned off via IC1c.

This means that the relay coil will be energised for about the duration of the RC time-constant. The relay isn't necessary if a 1V4 voltage drop from the supply is tolerable for a circuit. However, the current available is limited by the two transistors' capability.

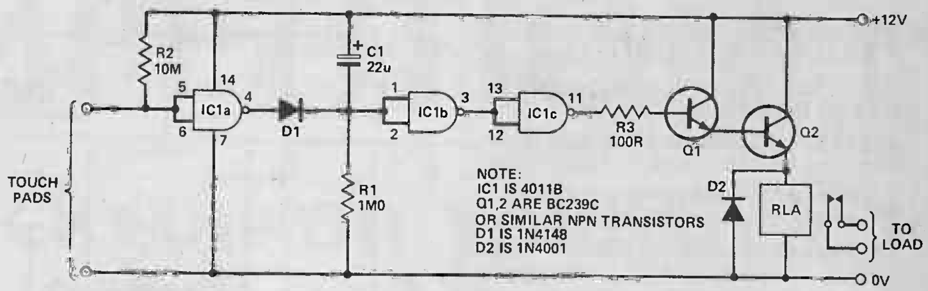
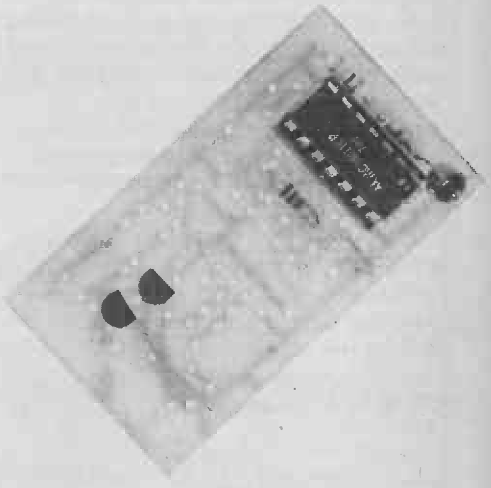


Fig. 1 Circuit diagram of touch switch.

PARTS LIST

Resistors (all ¼W, 5%)	
R1	1M0
R2	10M
R3	100R
Capacitors	
C1	22u 16V tantalum
Semiconductors	
IC1	CD4011B
Q1,2	BC239C (or similar)
D1	1N914
D2	1N4001
Miscellaneous	
RLA	12 V relay, coil resistance greater than 185R
PCB	



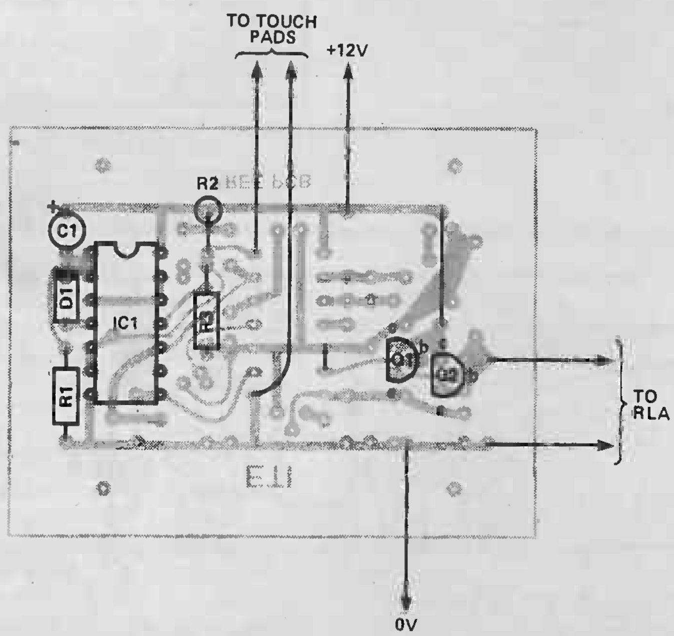


Fig. 2 Component overlay.

SOUND-TO LIGHT UNIT

Feel like flashing? Don't get arrested — build this sound-to-light unit instead! Design and development by Andy Elam.

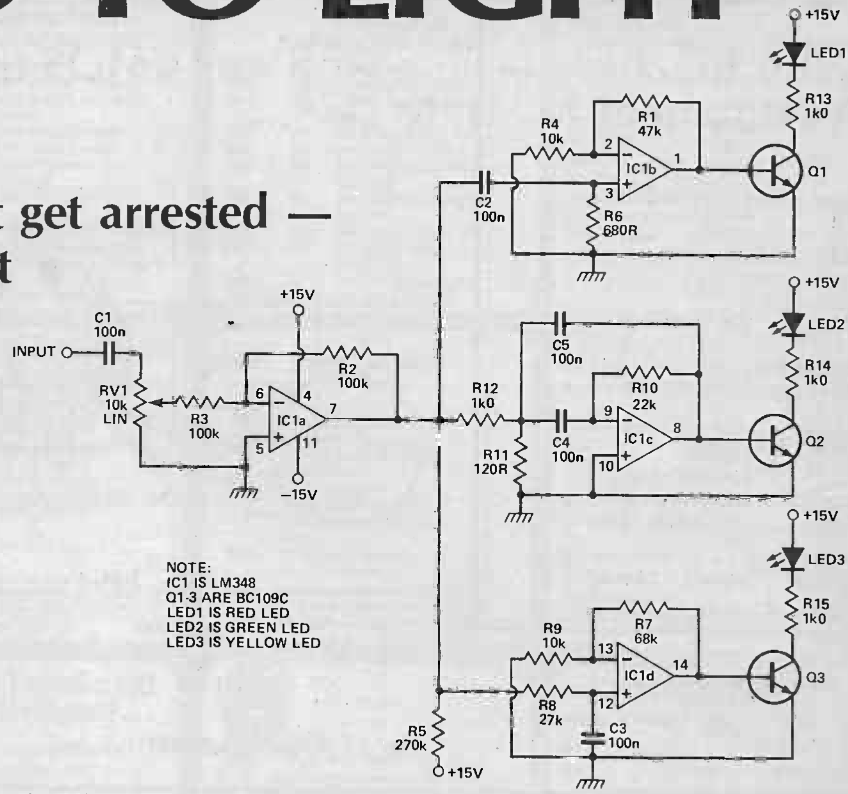


Fig. 1 Basic circuit diagram.

This miniature sound-to-light circuit uses an electronic element, the active filter, that, despite the trepidation some beginners may feel, has become a basic building block in electronics. The system takes the audio signal from a radio cassette player or other piece of audio equipment and lights up the corresponding light emitting diodes depending on the frequency components of the signal; using opto-coupled triacs, mains-powered lighting can be controlled — more on this later.

The circuit should be constructed as shown in the overlay diagram with all the external connections made carefully. The input signal may be taken directly from the loudspeaker terminals of a radio or cassette player, or the output for an earpiece may be used providing the loudspeaker is not switched off. In use, RV1 can be adjusted to get the most pleasing effect, with the lights flashing in time to the sound source.

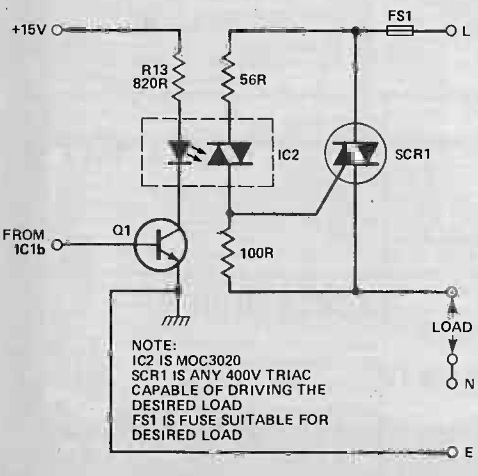


Fig. 2 Circuit to drive mains-operated lights. Note: IC2 is MOC 3020, SCR1 is any 400V triac capable of driving the desired load, FS1 is fuse suitable for desired load.

HOW IT WORKS

Three types of filter must be used, one which passes low frequencies, one which passes the mid-band frequencies, and one which passes high frequencies. Thus, low-pass, band-pass and high-pass filters are needed.

The first element in the circuit is a level control and amplifier. The gain of the amplifier can be increased by increasing the value of R2, in order to provide sufficient signal to drive the filters. The circuit also provides a buffer between the signal-providing circuit and the filters.

IC1b provides the high-pass section, IC1c the band-pass and finally IC1d the low-pass. The high and low pass sections are actually passive filters, buffered by IC1b and IC1d respectively; the band-pass filter around IC1c is the only true active filter. When a signal has enough low frequency elements the low-pass filter permits its output to saturate and this switches the LED on. Similarly, with mid and high frequency elements, the mid and high LEDs come on.

Substituting the LED with the control inputs of an opto-isolated triac (see Fig. 2) and reducing R13, 14 and 15 to 820R will enable you to control mains-powered lights.

In Fig. 2 the circuit for one control channel only is shown: the other two will be identical. Note that all the circuit to the right of the opoisolator is at mains potential: use extreme caution when connecting to the mains and ensure that all components are enclosed within an earthed metal container or plastic box. If the common terminal of the main unit isn't earthed already, then you should connect it to earth as shown.

PARTS LIST

Resistors (all ¼W, 5%)

R1	47k
R2,3	100k
R4,9	10k
R5	270k
R6	680R
R7	68k
R8	27k
R10	22k
R11	120R
R12,13,14,15	1k0

Potentiometers

RV1	10k linear

Capacitors

C1-5	100n ceramic

Semiconductors

IC1	LM348
LED1	any red LED
LED2	any green LED
LED3	any yellow LED

Miscellaneous

PCB

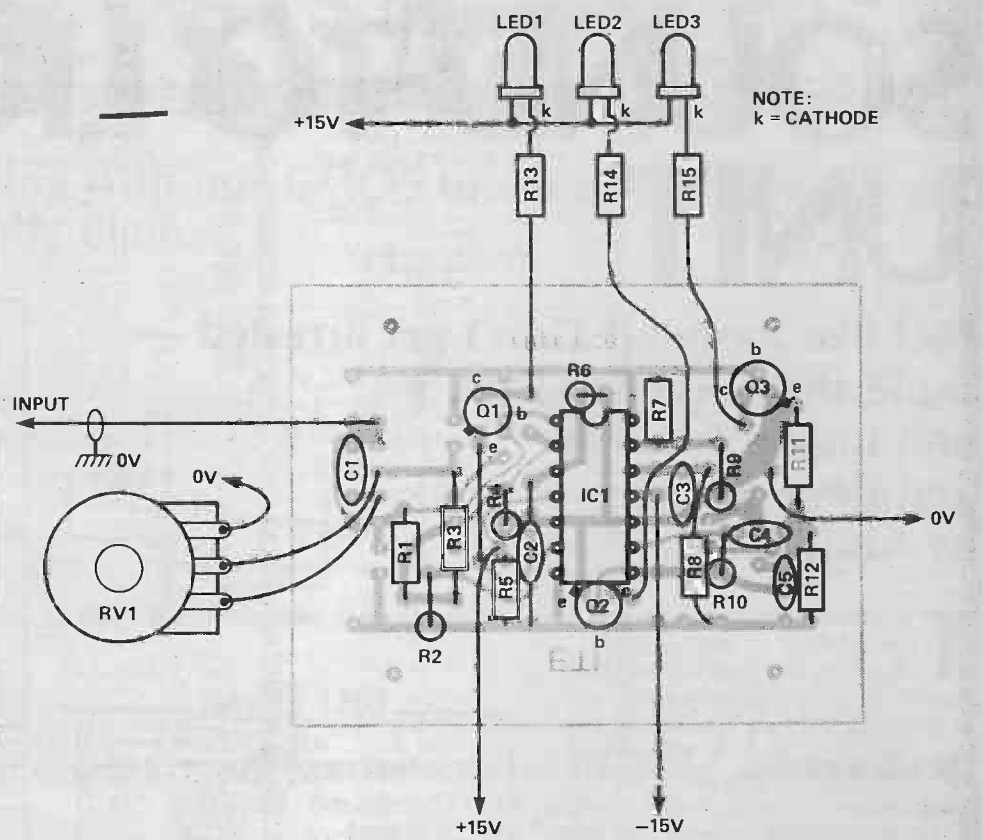


Fig. 3 Component overlay.

ETI

AUDIOPHILE

A guide to some of the heavyweights of the hi-fi market and the fork-lift truck you'll need to move them, by Ron Harris.

I knew I should never have started this. A month ago the idea of taking some of the more unusual amplifier types and comparing them seemed a marvellous idea. Carver's Cube, Denon's Class A, Hitachi's MOSFET etc. All are around a similar power and specification on paper and it would be interesting indeed to see what differences manifested themselves amongst test loads and listening tests.

Like all good ideas it gets worse once you try and *do* it! Amplifiers are OK but people can be infuriatingly people-like! Try and get the same four or five pairs of ears in the same place at the same time on several occasions and you've got confusion, indecision, stupidity and intransigence to cope with.

Carver's famous cube.

Why can't people be as straightforward as amps? You can always pull the plug on an amp if it gets awkward. Try that on a 'people' and you'll get smashed around the head. Never again.

As you may have gathered it is the listening tests which have caused the greatest problems in this project. With the exception of one exploding test load (over..heating!) the electronics have behaved beautifully. With *no* exceptions the panel have behaved normally for them, ie bloody awkward.

Just for a finale, two major Japanese manufacturers, Sony and Trio, have been less than speedy and have yet to deliver units for the final tests. Hence at present I can only relate our intention to include the Esprit amp from Sony and the well-regarded L08C from Trio. If they appear soon there is hope. If not — well, let the guilty be seen to be stood before the mass and named, in all their vain unglory.

Each of the amps was put through a test-bench session to measure all that can be reliably measured and then extensive listening tests were (and still are!) set up to attempt to see if the vast divergence in operating philosophy produced any discernable audible benefit. A common preamp was used for all the tests, with a common record-playing source. The turntable was my well-trusted Thorens TD160S with an SME series III pickup arm. The main cartridge used was a Shure V15V, and a Dynavector Karat Ruby was also employed, within the main listening tests, for reasons which will become apparent later.

That Which Goes Before

In order to be able to test the power amps fairly, a reliably transparent preamp had to be used. Since I know there are as many candidates for this as anything else I don't propose to go into great detail or debate on the subject. I chose the Denon PRA 2000, since I regard it as the most unimpeachable piece of equipment around. Perhaps Audiophile should have a look at a range of preamps — but not until a case of wine or two (at least!) has passed away will I consider it. That way lies madness. The speakers used were, as always, KEF 105 IIs.

The PRA 2000 is marketed very much as the Denon flagship. It is beautifully made and finished — with little apparent care for cost. A very high quality rosewood sleeve adorned the sample I received and it is the standard finish, I am told.

Inputs catered for are three phono (one moving coil), two tape decks, auxiliary and tuner. Each is push-button selected from the front panel and is 'FET faded' in and out of circuit with its own little LED on the front panel — in case you suffer instant amnesia and forget which input you're using. In addition, a 'pre-set' switch will allow you to choose which of the inputs become active upon switch-on.

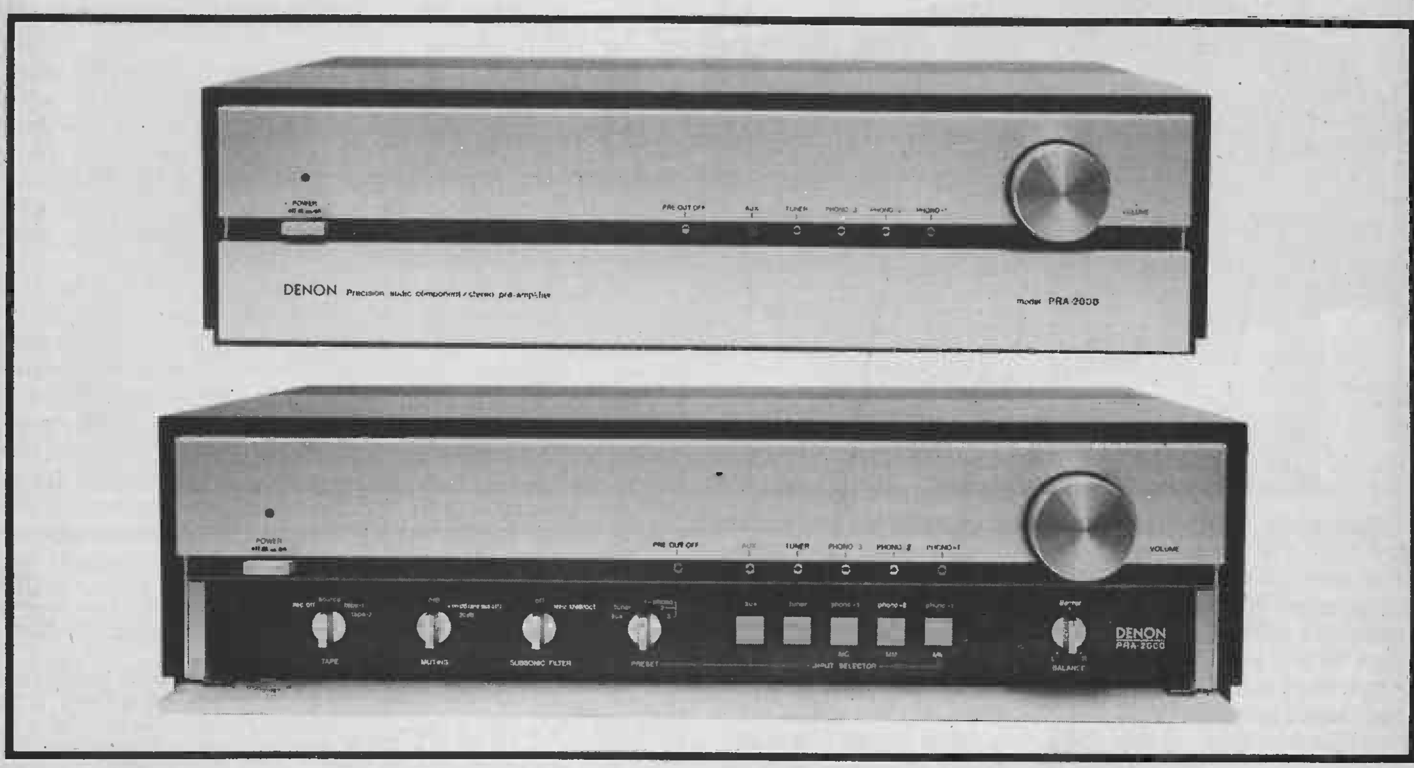
Phono Specialities

Denon are especially proud of their phono amplifiers in the PRA 2000. The basic circuit is a bootstrapped cascode circuit, run off 150 V rails to ensure it never clips! (Overload occurs at well over 500mV and clipping at *50V* would you believe?) RIAA deviation has been kept well inside $\frac{1}{2}$dB across the audio spectrum — and well beyond — and feedback equalisation is employed across two stages of amplification.

The head amp built into the PRA 2000 is of very similar design to Denon's separae (and acclaimed) HA-1000 unit.

On the test bench this circuitry distinguishes itself for its low noise, incredibly low distortion and seeming immunity to overload. Technically it's as perfect as you could get — given that cost is not a design restraint. Listening to the PRA 2000 does nothing to detract from the impression of perfection, either. This is as transparent a piece of hi-fi as any I have heard. I shall describe the sound it has only by saying NONE and hope you will make the correct inferences from that monosyllabic review comment!

Output levels from the 2000 are high enough to drive any amp, and we encountered no problems with any of the units in the test. This allowed us to set up each power amp for equal perceived volume with a test signal before commencing the listening sessions. Overall the 2000



The two faces of the Denon PRA-2000 preamp.

proved an ideal choice. It performed brilliantly and consistently. There is nothing at I could find to criticise either in the sound or in the technical performance. I can only (highly) recommend it to anyone with the money to spend and the urge to attain the highest possible quality from their signal sources.

Powerful Arguments

Due entirely to there not being enough space in this magazine you're holding, I'm going to have to divide up this Audiophile into two instalments. Four pages isn't really enough to do justice to any one of the amps herein, let alone all of them.

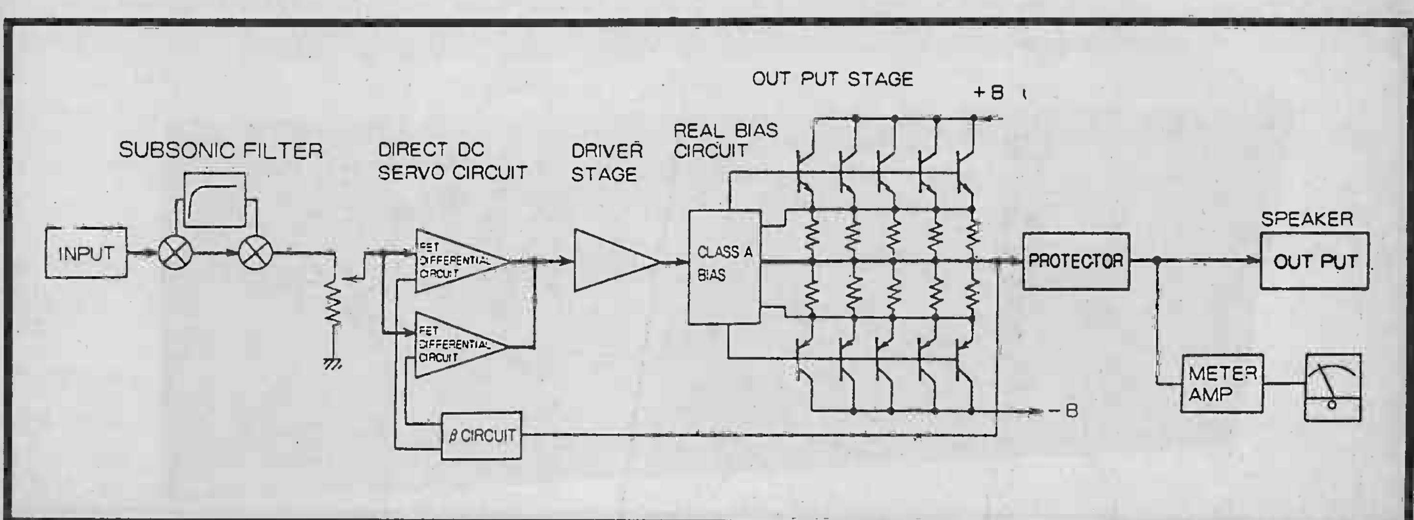
The editor (no it's *not* me anymore. As of this month those of you that read the contents page will have noticed that Dave Bradshaw is in that position. Treat him gently, he's only little!) will not give up any more space, so it's Part 1 this month, and 'Son of Audiophile, Part 2' next issue.

The test-bench results will all be presented in standard form to ease comparison. Looking down the tables there are no doubt some tests not there that you would have liked to see. Trouble is there are hundreds we could have done and even considered, before settling on a set basic formula. Listening tests were conducted with the amps in groups of three or four, with the groups being swapped around as we went. No attempt at 'live versus recorded' comparison were made, due to time, money and severe doubts as to authenticity and relevance of the technique!

Each of the amps was individually autioned over a period of time, in my own system, so that I had my own chance to assess what I thought of them. I might add that I was the mug working that comparator during listening tests and so did not score the units under test — because I knew what they were!

Hitachi 9500 II

Hitachi have been the major exponents of MOSFET-fi for many years now, and the 9500 is their new state-of-art design, producing over 120W using these devices. Totally



Block diagram of the Dennon POA 3000 power amplifier.

Hitachi HMA-9500 — try and pick it up and you'll find out why it's got the handles.

separate PSUs for each channel are employed, as you can see from the photo, with screening cases over both sides. The unit is big, very heavy and very black. Reminiscent of valve amps in appearance. If you think those handles front and back are redundant, just try lifting the thing sometime. (But who's got four hands? Ed.) The heatsinking proved more than adequate to keep the box touchable, even at my manic levels.

The circuitry of the 9500 II is fairly straightforward, employing cascode outputs to obtain safe operation at high voltage levels. A long-tail pair input stage is used and a current limiter protection stage is inserted prior to the drivers, to cut off the output in times of dire emergency. Unlike some protection circuits I could name, this one remained unobtrusive and did not appear to be tripping during music replay. The output stage is very conservatively rated; this probably means that the protection is set way above normal levels anyway.

Testing Times

As you can see from the results, the 9500 II turned in an excellent technical performance. The burst power of 217W could perhaps be a little higher taking into account the massive PSUs it has, but then if I remember correctly the other Hitachi MOSFET, the 7500 II, had a similar behaviour pattern when run as a stereo amplifier. (We are using two 7500 IIs in these tests, bridged to give 157W per channel.) Curious that.

Headroom is thus adequate rather than exceptional. All other results are exemplary.

In use I found the 9500 II to appear more powerful than it actually is. One of the nice spin-offs from using MOSFETS is that they overload gracefully, generating even harmonics in the process which are far more acceptable to the ear than the odd (especially third) harmonics produced by overworked bi-polar stages.

As you would expect from an amp of this class, the sound quality is very good indeed. There was never a time when the 9500 II sounded strained or troubled and it portrayed all types of music well. The only criticism I would make is that against amps such as the Denon and Carver, it tended to sound a little full and slightly heavy in the upper bass. This characteristic enabled me to pick it out from the others on listening tests. Individually used, though, I doubt whether anyone would find the effect troublesome, as the sound never thickened up, obscuring detail as poorer units can if overdriven in the bass.

Denon POA 3000

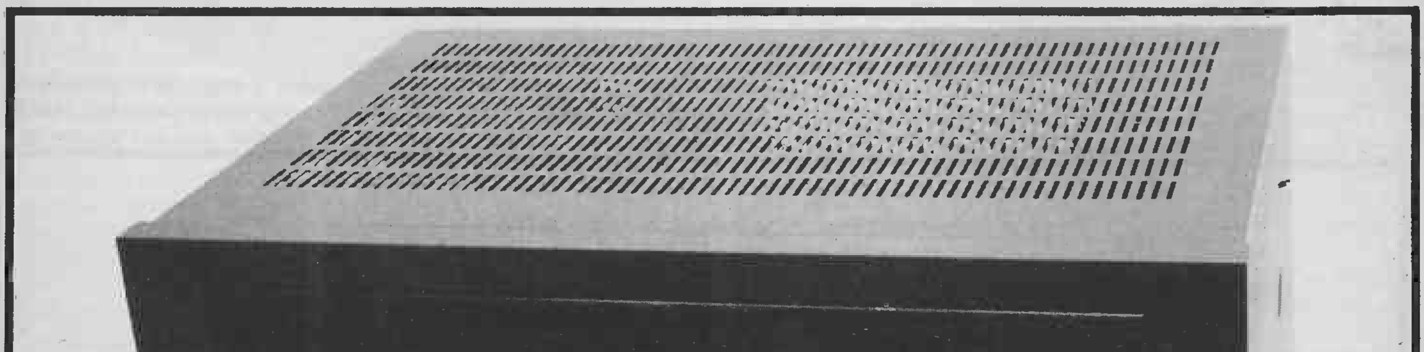
On grounds of price, I suppose the Denon is really out of the range of the other units in these tests, but it is perhaps the best of the commercial Class-A units and it is for that totally redeeming feature that it is included here.

Physically this is the biggest single amp I've ever come across. The case measures some 20"×20"×8" and it weights over 74lbs. Moving that around a lot does wonders for the soul and little for the temper.

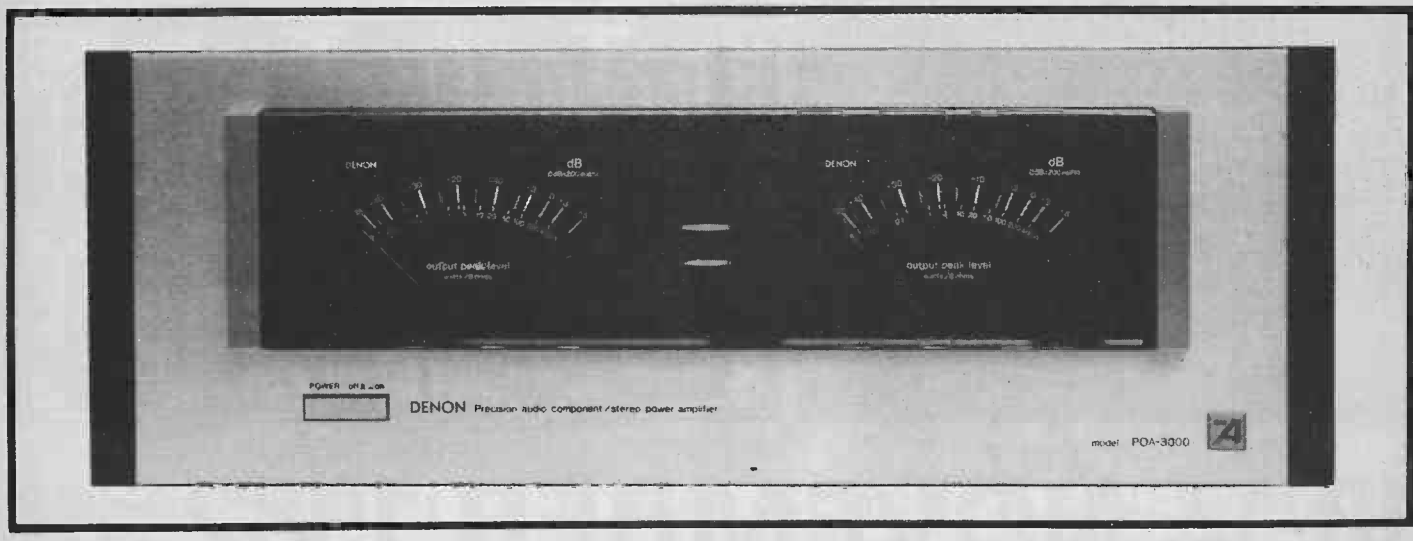
Separate PSUs are not used for each channel, but a 1kVA transformer is, along with 100,000uF of smoothing. In addition a second transformer feeds a highly stable 72V to early stages of the circuitry. There is extensive protection within the PSU to handle both the enormous switch-on surge and any fault condition that might occur.

Denon claim that they have 20 patents pending on the circuitry of the 3000, mainly in increasing the efficiency of the Class-A output from its usual 25%. They call the process 'real-time bias' and are very tight-lipped about what that means.

The output stage itself is composed of 10 power tran-



Hitachi HMA-7500 — similar to the 9500?



The Dennon POA-3000; definitely a fork-life truck job.

sistors per channel, in two parallel sets of five. Each is rated at 150W and has an f_t of 100MHz. (The slew rate of this amp is incredible — over 250V/us, measured at the speaker terminals.)

Another of their 20 patents lies in the use of ultra wide-band driver stages (f_t greater than 400MHz) employed in an emitter follower composed of cascoded small signal types. This is to reduce the high-frequency power roll-off brought about by the junction capacitance in power types.

TEST RESULTS

PRA-2,000 Pre-amplifier

MC input (1):	
Sensitivity:	0.1mV, 100R
Overload:	(1% THD) > 30mV
MM input (2):	
Sensitivity:	2.5mV, 50k
Overload:	(1%THD) > 500mV
THD:	0.01% (20Hz-20kHz)
S/N Ratio:	−86dB (MM); −79dB (MC)
Separation:	85dB (MM); 65dB (MC) (Both 20Hz–20kHz)
RIAA Deviation:	±0.1dB (Measured at record output 1)
AUX/TUNER	
Input sensitivity:	150mV, 50k
THD:	< 0.01%
TIM:	< 0.01%
IM:	< 0.01%
S/N Ratio:	101dB
Separation:	> 100dB
Frequency Response:	20Hz–20kHz ±0.2dB (to 100kHz -0.5dB) (Measured at preamp output)

(The POA 3000 has a power bandwidth in excess of 150kHz).

Put To The Test

One of the Denon's first acts under test was to exceed just about all the limits of the test gear available. Its power delivery is awesome and not a little worrying. Running it at full output with a sine wave it consumed some 1210W of mains power: this is equivalent to an efficiency of around 32%. Better than you'd expect with Class-A.

Technically there is nothing to criticise at all and I am unable to find a single flaw in the POA 3000's abilities. All they've got to do now is make it cost £100 and not £1100 and get it into a box 10″×10″×3″. Could be on to a winner there, no messing.

Trying to describe what the POA 3000 sounded like is to run out of superlatives very early on. It is open, detailed, extended at both ends of the audio spectrum and never anything more than neutral. It gives an uncanny reality to all that it plays and restores a little of one's faith in LP records as a hi-fi source. This is Class-A as never before, and I'll say here and now that I personally thought the Denon left all the rest of the amps for dead! Not everyone agreed with that however, and the listening tests proved very entertaining — but you'll have to wait for next month to find out what they were.

Next month our intrepid ex-ed continues his fearless foray into the world of super-fi amps with the listening test results, but no pictures of Felicity Kendal, I'm afraid.

Test Results	RMS Power (into 8R) 20Hz-20kHz (W)	Burst Power (into 8R) (W)	THD% (20Hz-20kHz)	Intermodulation Distortion (%)	Power Bandwidth (Hz)	S/N Ratio (dB)	Damping Factor	Input Sensitivity And Impedance (mV/k)	Channel Separation (20Hz-20Hz) (dB)	Frequency Response (20Hz-20kHz) (dB)	Dimensions (mm)	Price
Denon POA 3000	194	305	< 0.002	< 0.001	5/100k	120	154	1000/50	87	±0.1	495×188(H)×495	£1100
Hitachi 9500 II	136	217	< 0.01	< 0.01	7/100k	105	81	1000/47	94	±0.5	435×192×410	£600
Carver M-400	210	520	< 0.01	< 0.01	DC/100k	94	48	1000/50	74	±1	180×180×180	£430
Hitachi Dual 7500 II (bridged)	157	283	< 0.01	< 0.01	DC/180k	120	52	1000/40	> 120 (see text)	±0.5	435×330(H)×320	£550 (for two)

ETI

electronics today

OCTOBER 1982 VOL 11 NO 10

Dave Bradshaw: Editor
Peter Green: Assistant Editor
Nicola Trevett: Editorial Assistant
Rory Holmes:
Phil Walker: Project Editors
Gary Price: Advertisement Manager
Ron Harris B.Sc: Managing Editor
T.J. Connell: Managing Director

PUBLISHED BY:
Argus Specialist Publications Ltd.,
145 Charing Cross Road, London WC2H 0EE.
DISTRIBUTED BY:
Argus Press Sales & Distribution Ltd.,
12-18 Paul Street, London EC2A 4JS
(British Isles)
PRINTED BY:
QB Limited, Colchester.
COVERS PRINTED BY:
Alabaster Passmore.

OVERSEAS EDITIONS and their EDITORS
AUSTRALIA — Roger Harrison
CANADA — Halvor Moorshead
GERMANY — Udo Wittig
HOLLAND — Anton Kriegsman

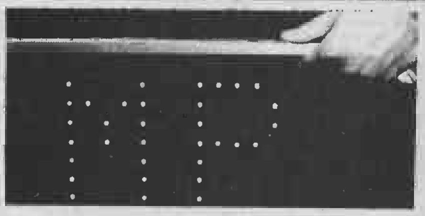
ABC Member of the Audit Bureau of Circulation

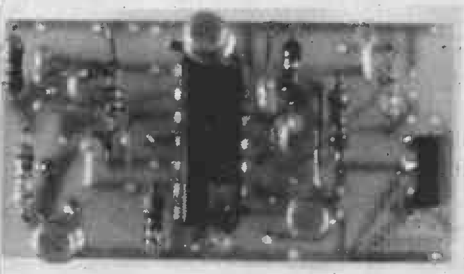
☐ Subscription Rates. UK £13.15 including postage. Airmail and other rates upon application to ETI Subscriptions Department, 513 London Road, Thornton Heath, Surrey CR4 6AR.

EDITORIAL AND ADVERTISEMENT OFFICE
145 Charing Cross Road, London WC2H 0EE. Telephone 01-437 1002/3/4/5.
Telex 8811896.

FEATURES

PROJECTS





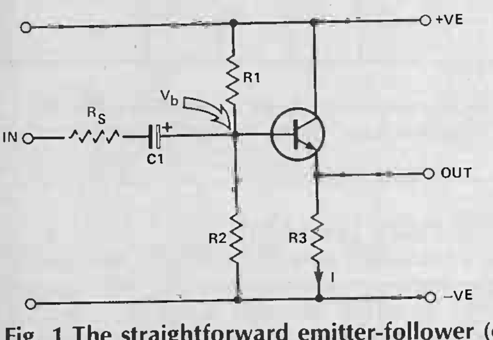
INFORMATION

CONFIGURATIONS

So far we've looked at the common-or-garden common-emitter configuration, but this month Ian Sinclair examines the not-so-common common-collector and common-base circuits. It's uncommonly good!

The usual configuration for a transistor amplifier is the common-emitter one that we have used in each circuit so far. A number of useful and interesting circuits, however, are based on the use of common-collector and common-base configurations, and even more interesting variations can be assembled using two or more transistors in these circuits.

The classic single-transistor common-collector (or emitter follower) circuit is shown in Fig. 1. As shown, this uses two resistors to set the DC base voltage, but these and the input coupling capacitor C1 can usually be dispensed with by using direct coupling (Fig. 2) to the collector of the previous stage when the common collector stage follows another amplifying stage. The design of the circuit is simple; just decide what current, I, that you want to flow in the transistor, and then the value of the emitter resistor R3 (in Fig. 1) is $(V_b - 0.6)/I$. The voltage gain is less than 1 (in other words, there is a loss of signal amplitude in the circuit) but the input impedance (resistance, if you're using low frequencies only) is very high and the output impedance is very low, which is ideal for a lot of purposes. It's particularly useful, for example, when placed between two common-emitter amplifier stages, because the emitter follower acts as a high resistance load for one amplifier stage and as a very low-resistance supply for the second stage. In this way, it's possible to get more gain from two transistors by adding a stage which causes a loss!



$R_{IN} \approx h_{fe} \times R3$

$R_{OUT} \approx R_S + \dfrac{\frac{R1.R2}{R1+R2}}{h_{fe}}$

$G \approx \dfrac{h_{fe} \times R3}{4 + h_{fe} \cdot R3}$

Fig. 1 The straightforward emitter-follower (common-collector) circuit and bias network.

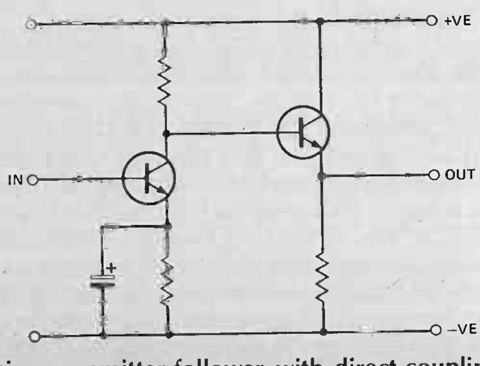


Fig. 2 Using an emitter-follower with direct-coupling.

Low Gain Is No Loss

Though the voltage gain of the emitter-follower is less than 1, and can be a lot less than 1 if the emitter resistor has a low value, the stage has a current gain which is about the same as the current gain measured for the transistor operating in common-emitter mode. This makes the emitter-follower a useful driver stage where extra current is needed, but some care is required when the circuit is used with pulses or high-frequency signals. There are inevitably stray capacitances across the emitter resistor, and these will be charged by the current flowing through the transistor when the base voltage goes positive. When the base voltage drops, however, the emitter voltage cannot change at a rate faster than that permitted by the time constant of the emitter load resistor and the stray capacitance, so that the trailing edge of a pulse has a slow fall time. This principle can be deliberately used in a demodulator for AM signals, by connecting a capacitor across the emitter resistor so that the time constant is long compared with the carrier wavetime but short compared with the wavetime of the modulation.

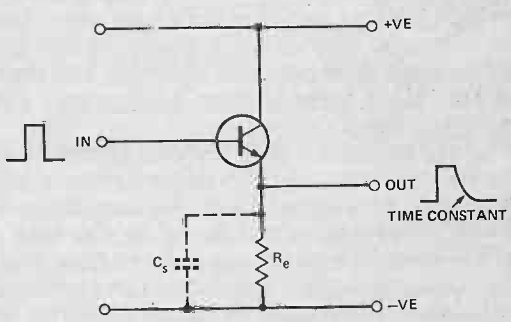


Fig. 3 The effect of stray capacitances on a positive pulse. The emitter-follower cuts off at the negative edge, leaving the stray capacitance to discharge through R_e.

Doubling Up

If pulses and high-frequency signals have to be used, a double emitter-follower is a better bet. The basic circuit is illustrated in Fig. 4a — it consists of an NPN emitter follower in series with a PNP one. The bias network uses two resistors R1 and R2, both of high value, and the diodes D1 and D2. The values of R1 and R2 have to be equal and large (100k to 2M2) to set the current through the transistors to a suitable value, usually 1 mA to 10 mA. Two parallel coupling capacitors are shown, but an alternative arrangement is a series coupling capacitor arrangement as shown in Fig. 4b. We'll look at this particular configuration in more detail in a later part when we consider power output stages, because it's the basis of most output circuits in transistor amplifiers.

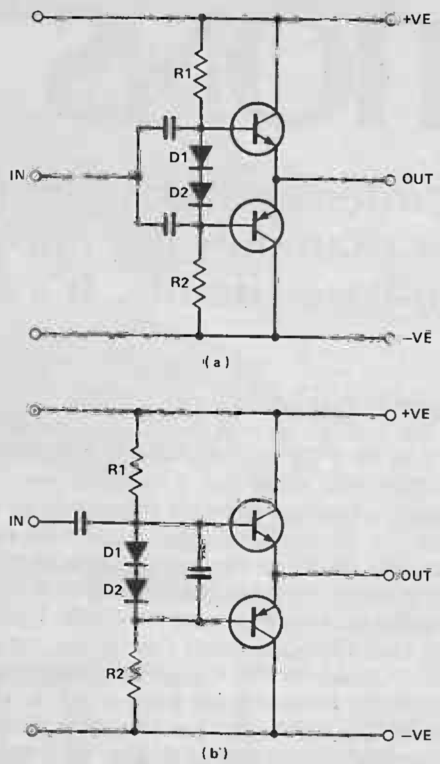


Fig. 4 a and b Two different arrangements of a double emitter-follower, using PNP and NPN transistors.

Meantime, take a look at the arrangement of Fig. 5, which is a type of double-emitter-follower. This circuit is often referred to as a Darlington Pair, a name I prefer to reserve for the version of the circuit which uses a load resistor in the collector circuit of both transistors. Bias is arranged in the same way as for a single emitter-follower, but the DC voltage drop between the input and the output is around 1V2, since there are two base-emitter junctions in series. The input resistance is very high, about $R_e \times h_{fe1} \times h_{fe2}$, in parallel with the bias components, and the output resistance is very low, about $R_s/(h_{fe1} \times h_{fe2})$. The current gain is $h_{fe1} \times h_{fe2}$, which is also very large. For example, if we use transistors with $h_{fe} = 100$ for both stages, then the compound current gain is 10,000, the input resistance with $R_e = 10k$ is 1M0, and the output resistance when the source resistance is 10k will be 1 ohm! For a lot of applications, Q2 can be a power transistor with a low value of h_{fe}, and the circuit can be used to simulate the action of a power transistor with a high h_{fe} value. The Darlington circuit of Fig. 6 might be expected to have a very high voltage gain, but does not — there is only one amplifying transistor, and the signal feedback from the collector of Q1 back to its base will reduce the overall gain quite noticeably if the circuit is driven (as it usually is) from a high value of source resistance.

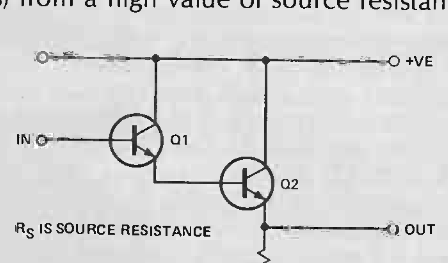


Fig. 5 A compound emitter-follower.

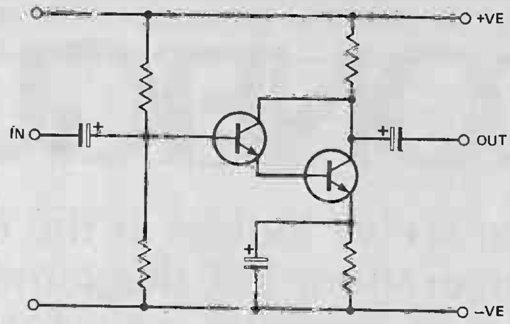


Fig. 6 A Darlington amplifier circuit.

Transistor Load? That's Cascode

The cascode circuit was one that was familiar to TV service engineers back in the days of valves (remember them?), but its transistor equivalent has never been so widely known, which is rather a pity. A cascode circuit consists of a common-emitter amplifier stage directly coupled to a common-base amplifier stage (Fig. 7). The input resistance is fairly low but the output resistance is very high, which makes the circuit particularly suitable for use with tuned-circuit loads or any other type of load which has a very high impedance. The gain is of about the same value as for a single transistor, but the impedance-transforming action (the reverse of the action of the emitter follower) can be very useful.

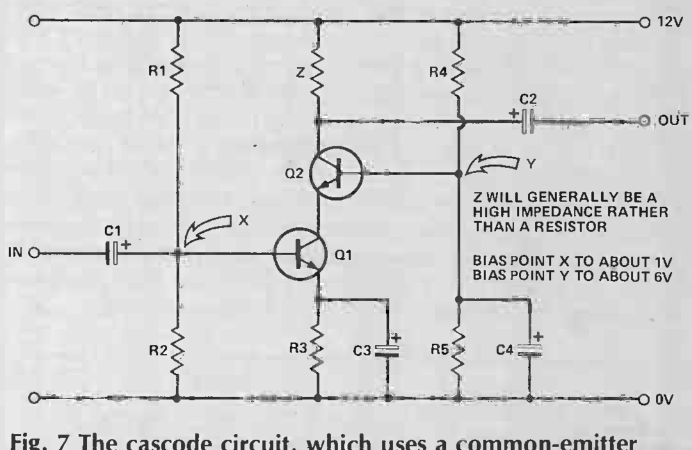


Fig. 7 The cascode circuit, which uses a common-emitter stage driving a common-base stage.

Long-Tailed Pairs Live On!

Of all the two-transistor amplifier circuits, though, the most commonly used is the long-tailed pair, simply because it features so much in linear ICs. The long-tailed pair, a circuit adapted from the days of valves, is a differential amplifier; basically this is an amplifier with two inputs, whose output voltage is proportional to the difference between the signal voltages at the two inputs.

The basic circuit is shown in Fig. 8. The emitters of the transistors are connected, and the bases are biased to about the same DC voltage. The bias is correct when both transistors contribute the same amount of current to the common emitter resistor, and this may need some adjustment unless the transistors are well matched. For ideal action, the value of R4 has to be high, so that large values of R5 and R6 are also needed. A true differential signal at the bases will cause one base voltage to increase as the other decreases, so causing one collector voltage to decrease as the other increases. This creates a large difference signal between the collectors, and ideally the total current through R4 does not change. For a common-mode signal, meaning a signal which is applied in the same phase to both bases, the collector signals will also be in phase so that the differential signal is, ideally, zero. The voltage gain, operated as a differential amplifier, is about the same as the ideal gain of a single transistor.

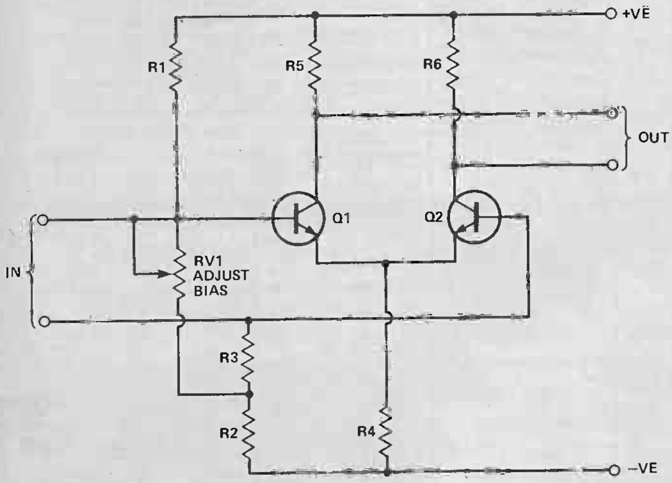
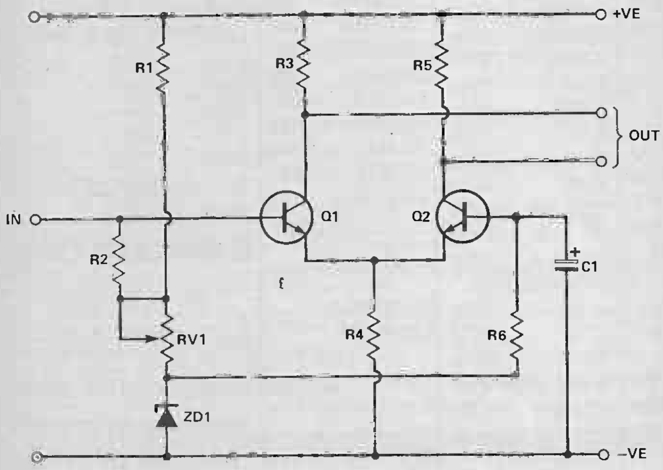


Fig. 8 The long-tailed pair (or balanced amplifier) circuit. This version is the balanced in, balanced out type.

The long-tailed pair is often used as a way of converting a single-ended input into a differential input for such purposes as driving push-pull circuits. The changes to the circuit to suit this purpose are shown in Fig. 9, illustrating in this case how a zener diode can be used to establish a 'half-supply' voltage level, as an alternative to using balanced power supplies. The voltage gain of the circuit when used in this mode is about the same as that of the differential mode.



BIAS: THE BASE VOLTAGES ARE SET BY THE VALUE OF THE ZENER DIODE. R4 SHOULD BE HIGH (22k OR MORE), AND THIS VALUE WILL SET THE TRANSISTOR CURRENTS I_{c1} AND I_{c2} SO THAT $R4(I_{c1} + I_{c2}) = V_b - 0.6$.
CHOOSE THE VALUES OF R3 AND R5 TO GIVE COLLECTOR VOLTAGE LEVELS MIDWAY BETWEEN THE SUPPLY VOLTAGE AND THE EMITTER VOLTAGE.

Fig. 9 A long-tailed pair used to convert unbalanced signals into balanced.

Transistor Tails

The restriction that affects this type of circuit is the value of the common emitter resistor. Since the value should be high to achieve true differential amplifier action, the currents in both transistors are forced to be small, and this is not always desirable unless the amplifier is used in an early stage. The way out of the problem is to use another transistor as the emitter load, as indicated in Fig. 10. The currents can then be set to suit whatever values are needed, because this is simply a matter of biasing. The 'tail' transistor will, however, act as a high resistance for AC signals, because this resistance is the output resistance of the common-emitter transistor. This is nearer to the type of differential circuitry that is used in linear ICs, and further refinements of the circuit are possible, though the effort is not really worthwhile if a linear IC can be used instead.

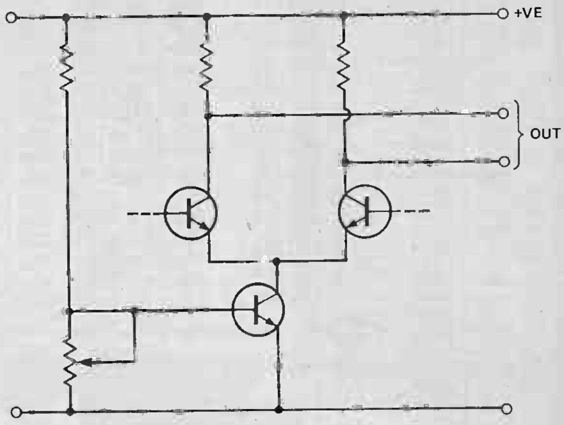


Fig. 10 Using a transistor as the 'tail' of the circuit.

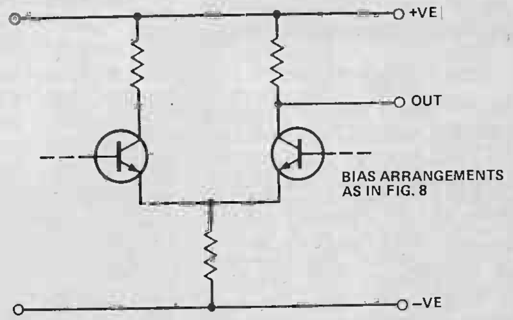


Fig. 11 Obtaining an unbalanced output at one collector.

The long-tail pair circuit turns up in all sorts of applications, and one of them is the conversion of differential signals to single-ended output as illustrated in Fig. 11. The gain in this type of circuit is only half as much as can be expected in the differential mode. Another frequently used circuit is the metering circuit of Fig. 12 in which the differential signals at the output of the long-tailed pair are applied to a bridge rectifier and used to drive a meter. No part of the meter circuit is earthed, and zero setting is carried out by adjusting the biasing of the differential amplifier. This is a very useful basis for an AC milliammeter circuit.

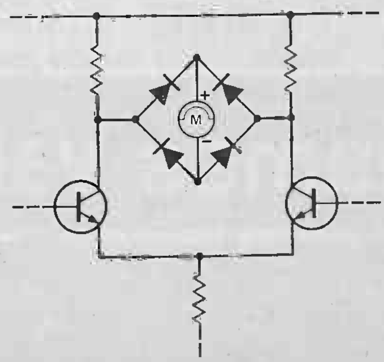


Fig. 12 Driving a bridge rectifier circuit.

ETI

MICROTUTOR PART 3

It's all very well being able to write machine code programs but unless you can store them on tape things are going to get a bit laborious. This month we look at the cassette firmware. Design by Tangerine Computer Systems.

The TANBUG software allows files to be dumped, verified with the memory contents, and read back into memory. Files may be named with a filename of up to six characters. Files are recorded at 300 baud in CUTS format and several error checks are incorporated. Filenames are compatible with the Tangerine Microtan system (only when used with hex keypad). Some experimentation may be required to find the correct recording and playback levels. Experience shows that on most automatic level recorders, the playback volume control can be left at maximum setting.

Dumping To Tape

The 'D' command is used to dump an area of memory to tape. Its format is.

D<START ADDR>,
<END ADDR>,
<FILENAME><CR>

The filename may be up to six characters long. Characters within it may be A–F, 0–9. To dump a program on to tape proceed as follows:

- Use the 'D' command but do not type <CR> yet.
- Start tape running in record mode.
- Hit <CR>. The VDU will respond with the filename being dumped, with an added appendix of .A to distinguish this file as being an absolute file.
- The cursor will disappear and the file will be dumped.
- The cursor will reappear when the dump is complete — the program returns to TANBUG.
- Stop the cassette.

Example: Type D400,410, F1, <CR>. The display will appear as follows:

D400,410, F1
F1 .A
■

The instruction dumped locations 400 to 410 inclusive, and called the file F1.

A question mark error will be generated if the command format is illegal, if the filename contains an illegal character, or if it is more than six characters long.

Examining A Tape

The 'E' command allows you to examine a tape to see that the file has been dumped correctly, and that it can be read back. This command searches the tape for the named file, then compares what it reads with the memory content. To examine a tape:

- Position the cassette on a piece of blank tape (ie a section with no recorded signal) somewhere before the file to be examined.
- Type E, <FILENAME><CR>. The VDU responds with the filename.
- Start the tape in play mode.
- When a file is encountered, the VDU will respond with the filename and dump start address.
- If this filename is not identical with the one specified, the previous step is repeated.
- If a read error is encountered, the message F(n) is printed, indicating a filename error. The program then goes to the fourth step.
- If the filename is identical, then the comparison will be initiated.
- If the comparison is correct, the program will return a cursor prompt and return to TANBUG.
- If the comparison is incorrect three types of error may occur.

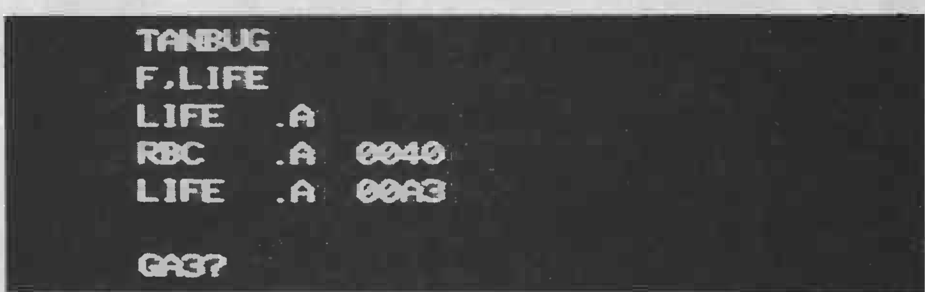
M(n) — memory error; contents of tape do not agree with contents of memory. (n) is the address of the fault.
P(n) — a parity error occurred when reading the data associated with location (n).
C(n) — a checksum error occurred at the end of the file; (n) indicates the file end address.

In all cases, after printing an error, the program continues to read data. Thus if only a few errors occur, they may be checked out by reference to their addresses.

Note that a VDU scroll may induce a parity error due to the time taken for a scroll. It does mean, however, that there are more errors than acceptable and the file should be re-dumped until error-free. As an example suppose there are two files on a tape, F1 and F2. You wish to examine F2, but position the tape at the blank leader.

E, F2

F2	.A		;prints your filename.
F1	.A	0A00	;prints first filename.
F2	.A	0400	;prints second filename.
■			;comparison correct.



A typical display when using the cassette firmware. LIFE is loaded and ready to run.

Or, with one memory error:
E, F2
F2 .A
F1 .A 0A00
F2 .A 0400
M0410
■

Location 0410 is at fault.

Tape Directory

The 'E' command may be used to obtain a complete listing of the tape contents, by rewinding the tape to the start and looking for a non-existent filename. Note that in this case it is necessary to exit back to TANBUG at the tape end by using the RESET key since interrupts are disabled in the cassette software. This procedure may also be necessary if the examine procedure gets very badly out of step due to a large number of errors.

Fetching A File

To fetch (load) a file into memory, the 'F' command is used as follows:

F,<FILENAME> <CR>

For example, typing F,F1<CR> looks for F1 .A and loads it into memory. Operating procedures and errors are exactly as detailed in the section on the examine command. Should an M error occur, a hardware fault is indicated because the program loads the input data to the memory location and checks it immediately afterwards.

If one program uses several different areas of memory (eg one area for subroutines and another for main code) it is necessary either to dump the whole area in one file, thus encompassing some redundant locations, or to dump in two files.

Error Messages

The following is a resumé of the error messages that may occur during tape operations.

M(n) — when examining, memory location (n) contained a different value to that read from the tape.

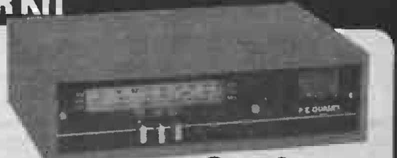
— when fetching, memory location (n) failed to be updated with the value read in (hardware error).

P(n) — a parity error occurred when reading the byte for location (n).

C(n) — a checksum error occurred during the tape read; (n) indicates the end of file address. Since a parity check is not infallible and will not detect two bits in error, a checksum is an additional data validity test. A checksum error will nearly always occur if a parity error occurs. If a checksum error occurs, but no parity error, the code must be listed and visually checked to determine where the error occurs.

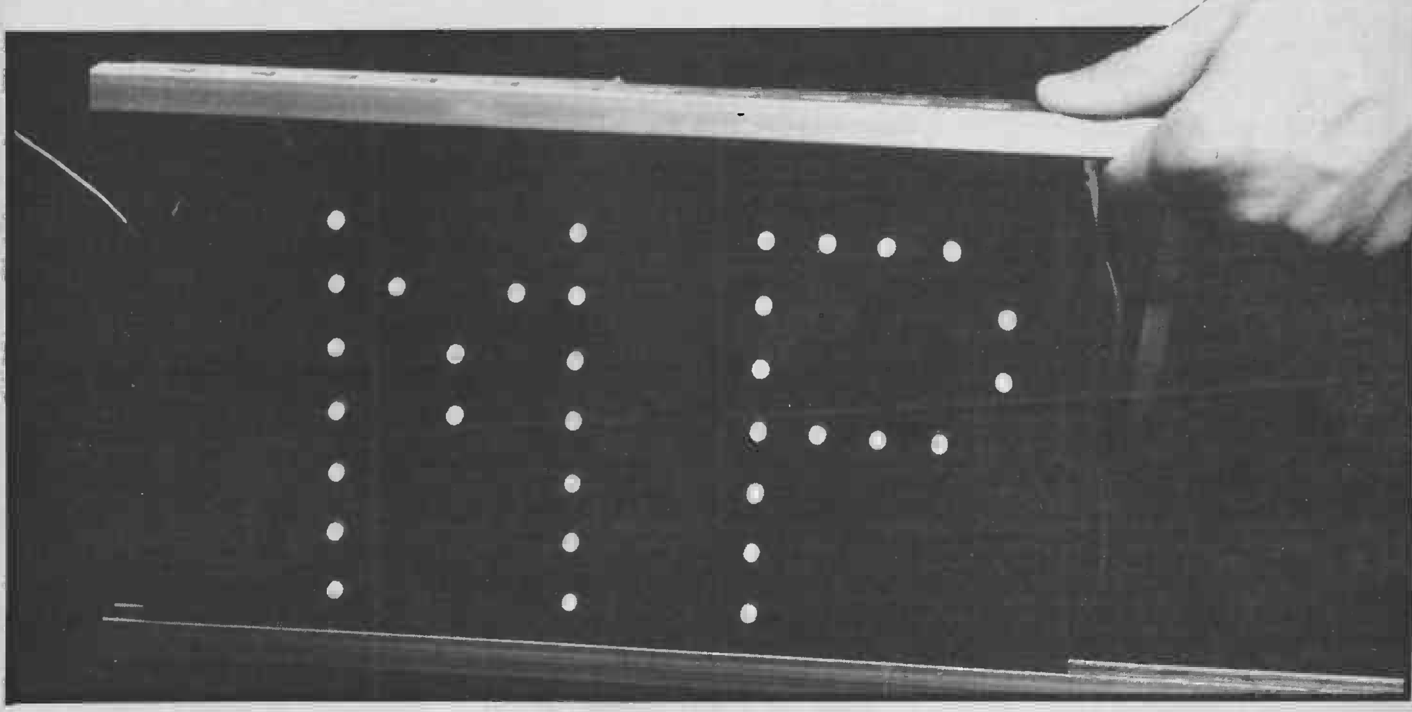
F(n) — an error occurred when reading the filename: (n) is meaningless.

If errors do occur, you should first try reading the tape again in case the error was due to mains-borne noise. If, however, the same error persistently occurs on re-tries, the tape is likely to be in error. ETI



MESSAGE PANEL

Wish fulfilment for ad-men, exhibitionists (!) and ego-trippers; see your name (or anything else you fancy) up in lights. Design and development by Rory Holmes.



MOST readers have probably seen moving message panels of the electronic type by now, either small shop window displays or the larger newsboard versions. They are ideal for advertising, description, news, or just providing information — a moving message in lights is unparalleled at drawing people's attention. Commercial message displays are costly items, being quite complex just in the sheer number of components. Although useful in shops, offices and the home, the chance to have your name in lights has until now been an expensive luxury. ETI decided to design a message panel that would be better suited to the constructor's budget — simple to build and easy to use. By simplifying the circuitry we came up with a design that was easily expandable by single characters and could be controlled in a number of different ways.

The message panel uses light emitting diodes as the illumination, characters being formed on a seven by five matrix of LEDs. The display can be built to any length using identical 'character cards' connected in daisy-chain fashion (see the PCB overlay diagram of Fig. 6); a new card can be simply added on to the end with direct wire links to the previous card.

Cooee Mr Shifter

The circuitry we have used employs shift registers to store and move the display pattern, each parallel output directly driving the LEDs rather than multiplexing them. Scrolling of the message across the display panel is thus achieved by simply clocking the shift registers as the character pattern data is presented to their inputs. The speed at which this is done determines the speed at which the message passes through the display panel. Since there is one data input for each of the seven rows of shift registers and one shift clock line the entire panel may be driven from one eight bit computer port.

The only other connections required are for the power supply and this can be an ordinary 9 V unregulated supply. Fig. 2 shows the circuit for the power supply we used — each card takes about 200 mA and therefore a 2A supply should do for about 10. Next month we shall feature a small interface PCB that allows the message panel to plug directly into a Sinclair ZX81 or Spectrum computer, complete with the software listings of BASIC programs for entering and running repeat messages of any length with the ASCII character set. We are also going to publish a custom control

SPECIFICATIONS

Requires a single 5 to 9 V supply (unregulated).
Characters are 6" high on a 7 by 5 matrix.
Each card consists of a 7 by 8 LED matrix.
One eight bit port drives the whole panel (seven row data inputs and one clock input).
Cards may be plugged together daisy-chain fashion for long character strings.
Any message scroll speed is obtainable.
Cost of components for each card is around £12.
Standard eight-bit shift registers are used for storing and moving the display pattern.

card that can store and run messages using battery-backed up CMOS memory.

Construction

We recommend that about six character cards are used for maximum readability, although even two cards will provide perfectly legible messages. They can all be constructed and tested individually (as time and money will allow). Solder in all the links on the PCB first, following the overlay diagram in Fig. 6. The seven links that connect in a line to the positive rail should be made with thick tinned copper wire, while the other 13 links are made with thinner tinned copper wire. If the wire is thin enough it may be laced through all the link connection holes as a continuous wire and then soldered up; this greatly speeds up the process. The resistors, capacitors and transistors should then be soldered in followed by the ICs. Be sure to check the component orientation at this point to save expensive mistakes later on. IC sockets may be used and are recommended to ease any replacement problems in the future. Also note that the components labelled R101, 102 etc are repeated seven times per character card, whereas the additional components (drawn separately in Fig. 1) are required only once on each card.

Now we come to the LEDs. We strongly recommend that good quality red LEDs of the high efficiency type are used, since this makes all the difference both to current consumption and readability of the display. As mentioned in Buylines an ideal LED, having even brightness and high efficiency, can be obtained in quantities of 200 from Zaerix Electronics. At around 11p each they represent good value for money, being sufficient for four character cards. The LEDs should be soldered in at a height of about 16 mm from the surface of the board; their cathodes all go to the 0V rails (the cathode is nearest to the flat).

The following construction method makes it easier to achieve a uniform height and neat rows. All the LEDs should first be inserted and pushed in to less than the required height; the board is then turned over onto a flat table top, and raised up to the right height on suitable blocks. The LEDs may be tapped on their leads to make contact with the table, thus ensuring they all reach the same height. Initially, only their cathodes should be soldered to the 0V rails. When they are all secure the board may be turned over to even up all the rows of LEDs and make any final adjustments before completing the soldering of their other leads. Vero terminal pins may be soldered in if desired to terminate the connections at the card edges; alternatively miniature single-way sockets or just direct wiring could be used.

Testing

When assembly is complete the board may be tested as follows. Wire up the 0V rail and positive rails to a 9V supply of about 500mA; a PP9 should suffice for one card, although the suggested mains power supply of Fig. 2 (suitable for powering 10 cards) would also be ideal. Now connect a square wave clock signal to the input marked clock on the overlay (preferably variable from about 1 to 10 Hz). If no signal CMOS circuit shown in Fig. 3 could be used. Hopefully all the LEDs should remain in their off states; the power-on reset to the shift registers ensures that the data outputs are all low, and the data inputs to the registors are all held low by the resistors R105, R205 etc. With one end of a crocodile clip lead on the 9V rail, touch the other end to one

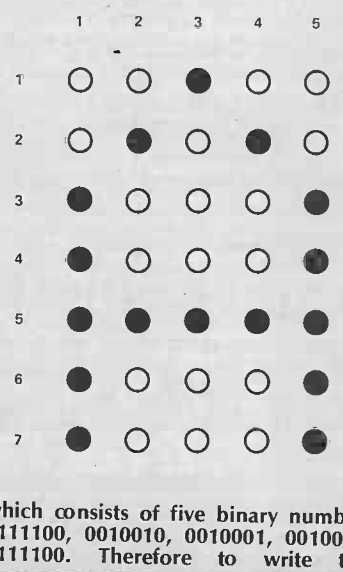
BUYLINES

Most of the parts are completely standard but be certain to get the B version of the CMOS 4015. The LEDs should ideally be 5 mm red high efficiency types as explained in the text. Zaerix Electronics Ltd will supply a suitable LED (the L531D) in quantities of 200 for £23.60 — you can find them at Electron House, Cray Avenue, St Mary Cray, Orpington, Kent BR5 3QJ.
Our PCB Service advert is on page 85.

HOW IT WORKS

The circuit operation of the message display panel is completely straightforward. Figure 1 shows the circuit for one row of eight LEDs - this circuit is identically repeated for all the seven rows of each character card. Essentially the message panel is just seven long shift registers (the total length, in multiples of eight, being up to the constructor). The state of each bit of the shift registers is displayed on an LED, and these form the matrix on which characters of the message are written. The shift clocks of all the registers are tied together to form a common clock which simultaneously shifts all the information through the registers. The patterns of display information presented at the seven register data inputs are thus shifted down the line of registers to form the 7 by 5 characters.

For instance, the character 'A' has the 7 by 5 pattern of

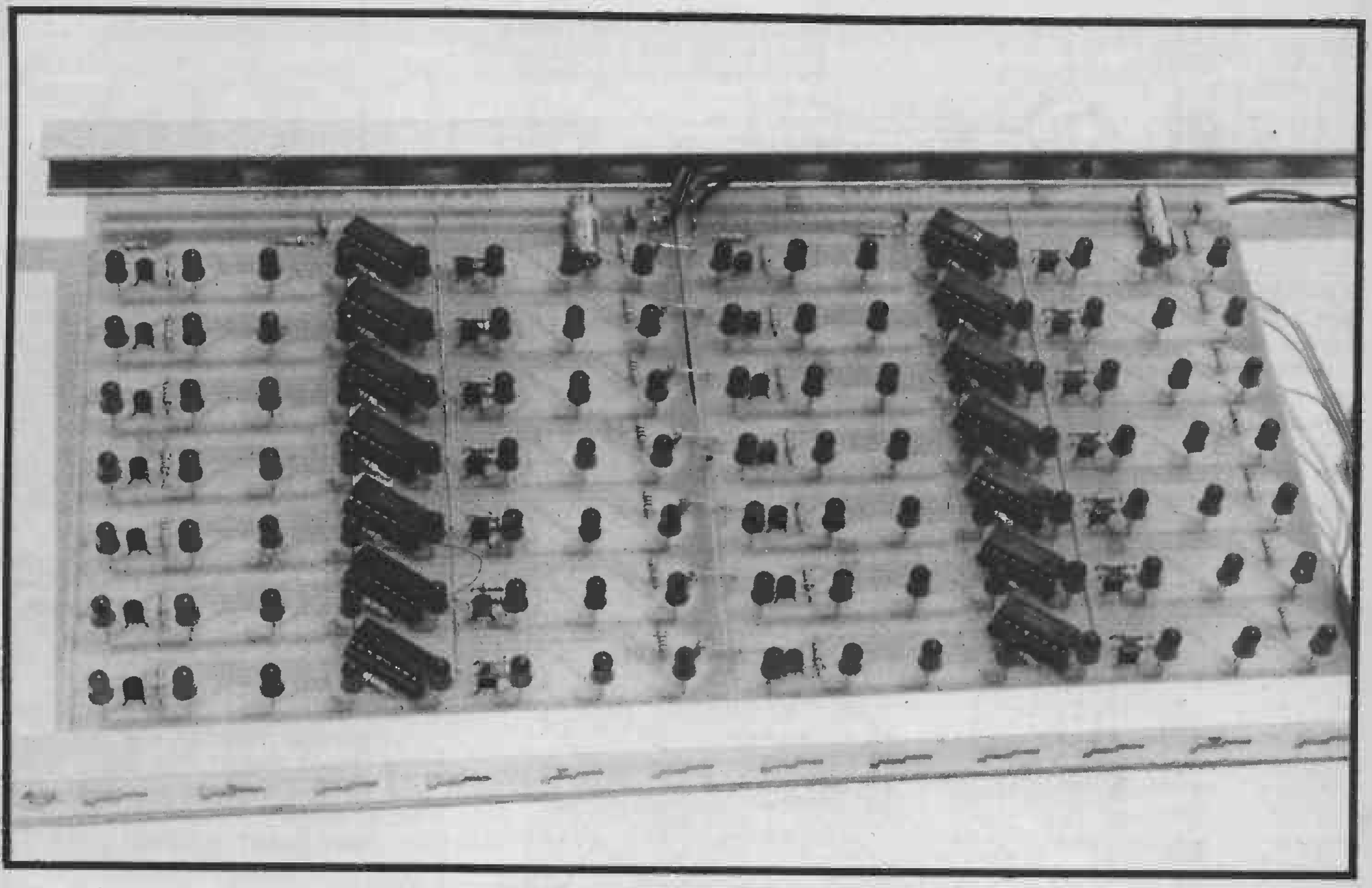


which consists of five binary numbers 1111100, 0010010, 0010001, 0010010, 1111100. Therefore to write this character onto the LED matrix these binary numbers are input as logic data to the seven row inputs, and the shift clock is pulsed briefly after each byte of data to move the display pattern down the columns. The character may then be scrolled, exactly as it is, down the display panel simply by repeated pulsing of the shift clock line.

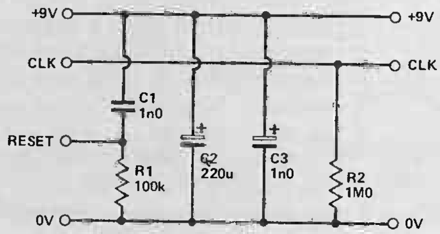
The actual circuit is based around IC1, a dual four-bit shift register. Both sections are wired together in cascade to produce an eight stage serial-in-parallel-out shift register. IC1 is used to drive six of the LEDs directly. The fourth output bit of each section, which connects in cascade to the next section, has been buffered by transistor drivers, Q1 and Q2, so that the LED loading on the logic levels does not affect the data transfer. The resistors R1 and R4 determine the current supplied to LED1 and LED5. The reset pins (6 and 14) of all the registers are tied together and taken to a power-on reset circuit formed by R1 and C1. This is to prevent the LEDs coming on when power is first applied.

Resistor R105 on each register input is not strictly necessary in a fully built panel, but it keeps the data inputs tied to a definite logic-low level, which is useful when testing and unplugging boards. Similarly R2, used once on each card, will hold the common clock line to logic low when not in use. C2 and C3 provide decoupling on an individual card basis.

The cards may be powered from any voltage between 5 to 9V. Since some of the LEDs are driven directly from CMOS no more than 9V should be used, as the current and dissipation become too high. At 9 V the LEDs should be quite bright, drawing about 11 mA each. For a standard character set there will never be more than 20 LEDs illuminated at once and therefore a total of only 200 mA is sufficient for each card. Ten or so boards could thus be powered from the simple power supply circuit shown in Fig. 3.

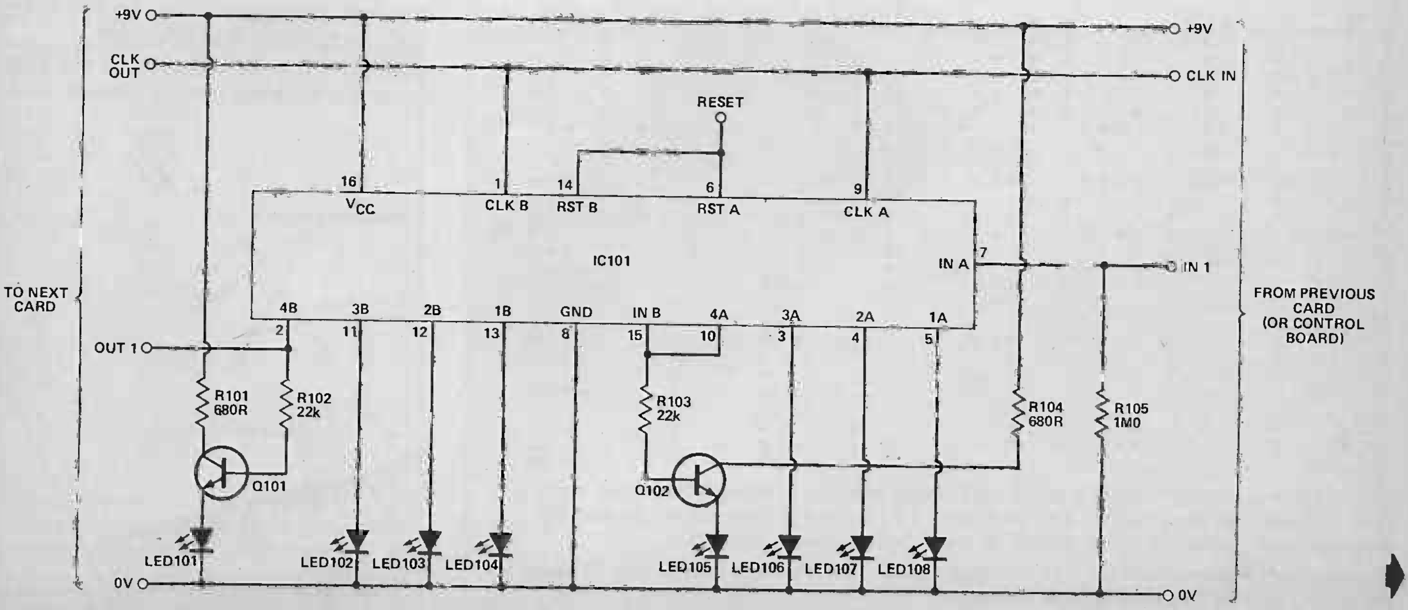


Here we have two character cards linked together and bolted onto the mounting frame (we used standard shelving bracket extrusion). The wiring to the computer port is connected to the right-hand board.



NOTE:
IC101 IS 4015B
Q101,102 ARE BC184L
LED101-108 ARE 5mm
RED LEDS (L53 ID)

Fig. 1 Circuit diagram for one channel, or row, of one character card. The components in the larger section are numbered R101 etc, and are repeated seven times on each card; the components in the smaller diagram are used only once per card.



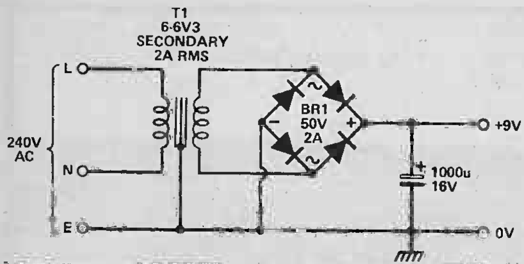
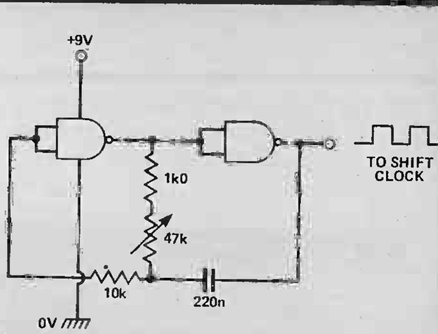


Fig. 2 (Left) Circuit diagram of a power supply with a rating suitable for driving 10 of our character cards.

Fig. 3 (Right) Circuit diagram of a simple clock generator which could be used to test the message panel.



of the data input pins; this makes a logic high data bit enter the shift register and causes illuminated LEDs to move down the shift register at a speed determined by the shift clock. If the data input is kept as a high, all the LEDs in one row will illuminate, and then successively turn off when the data input goes low. All seven rows should be checked in this manner.

Casing The Cards

The PCB has been designed to allow each card to be bolted into a rigid case. We used the standard aluminium extrusions available from DIY stores; the diagram of Fig. 5 shows how the panel can be assembled and covered with red filter plastic to improve the readability.

Character Control

To scroll information from a standard computer port into the shift registers, the clock line should be connected as the MSB (the order of the other bits depends on the character generating patterns). Whatever binary number (less than 128) is required on the LED column should then be output to the port, ie

POKE PORT, number

Since the MSB of an eight bit binary number less than 128 is 0, the clock line is low. Then 128 is added to this number to toggle the shift clock, ie

POKE PORT, number +128

When the number is output again the lower seven bits remain unchanged but the MSB switches high, clocking the shift registers on one place. This process is repeated to scroll the message across the panel. Figure 4 gives a suggested character set based on the ASCII code (decimal equivalents shown beneath); however, we've replaced the hash symbol (# with a £ sign, which is probably more useful in this application. As an example of the procedure given above, to display the letter F the numbers 127, 9, 9, 1, 1 must be output from the port (corresponding to 1111111, 0001001, 0001001, 0000001, 0000001, the bit-patterns of the five columns making up the letter).

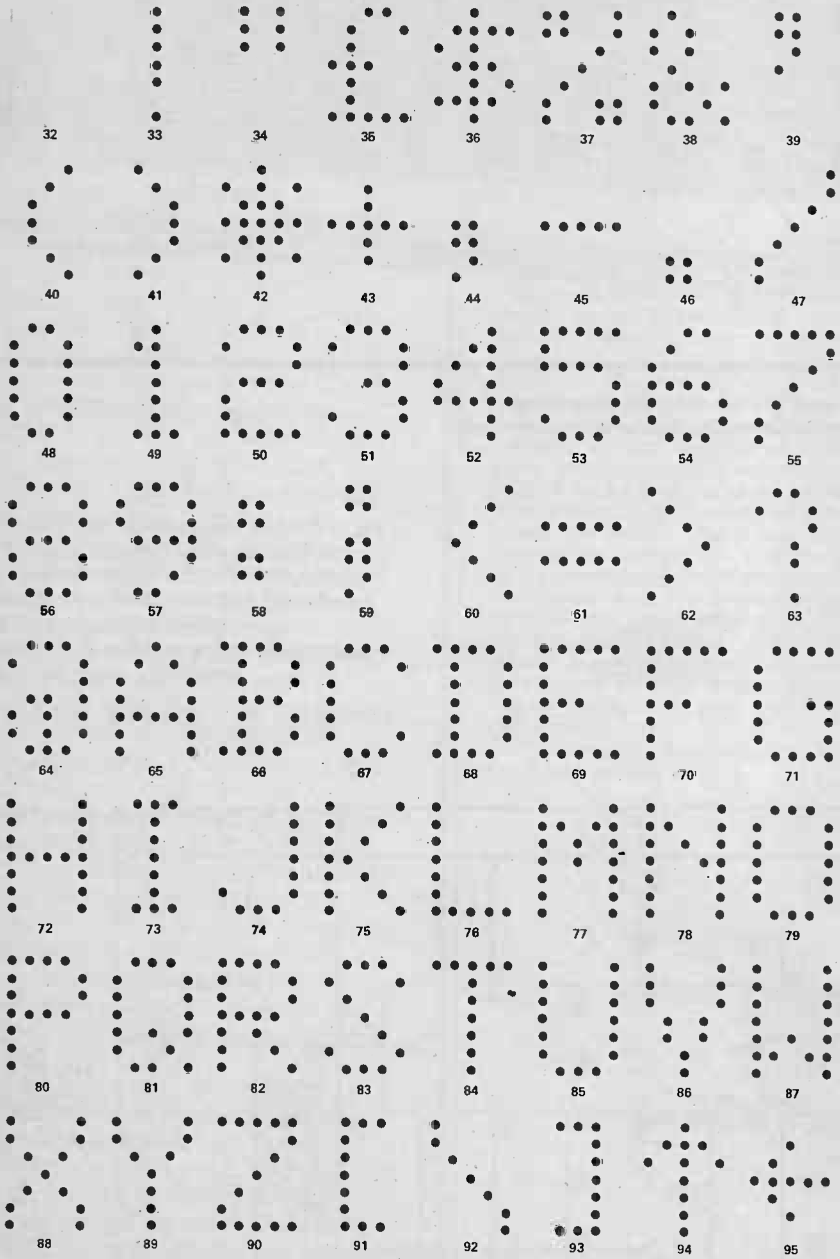
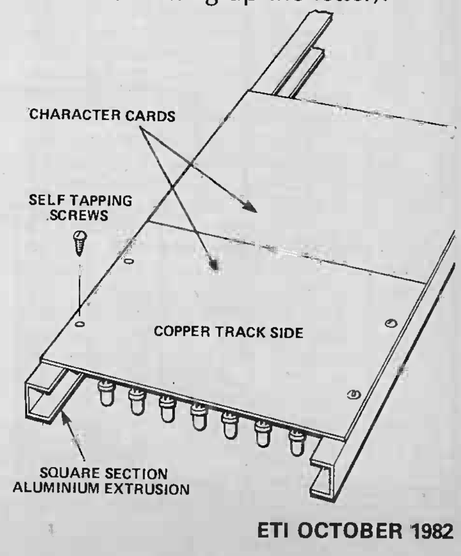


Fig. 4 (Above) A suggested character set for this project. Although based on the ASCII standard set, we've replaced the hash sign (#) with a £ sign; when displaying messages it's probably more useful to have both £ and $ available.

Fig. 5 (Right) Assembly of the ETI Message Panel. The red filter plastic can be stuck to the other side of the aluminium extrusion.



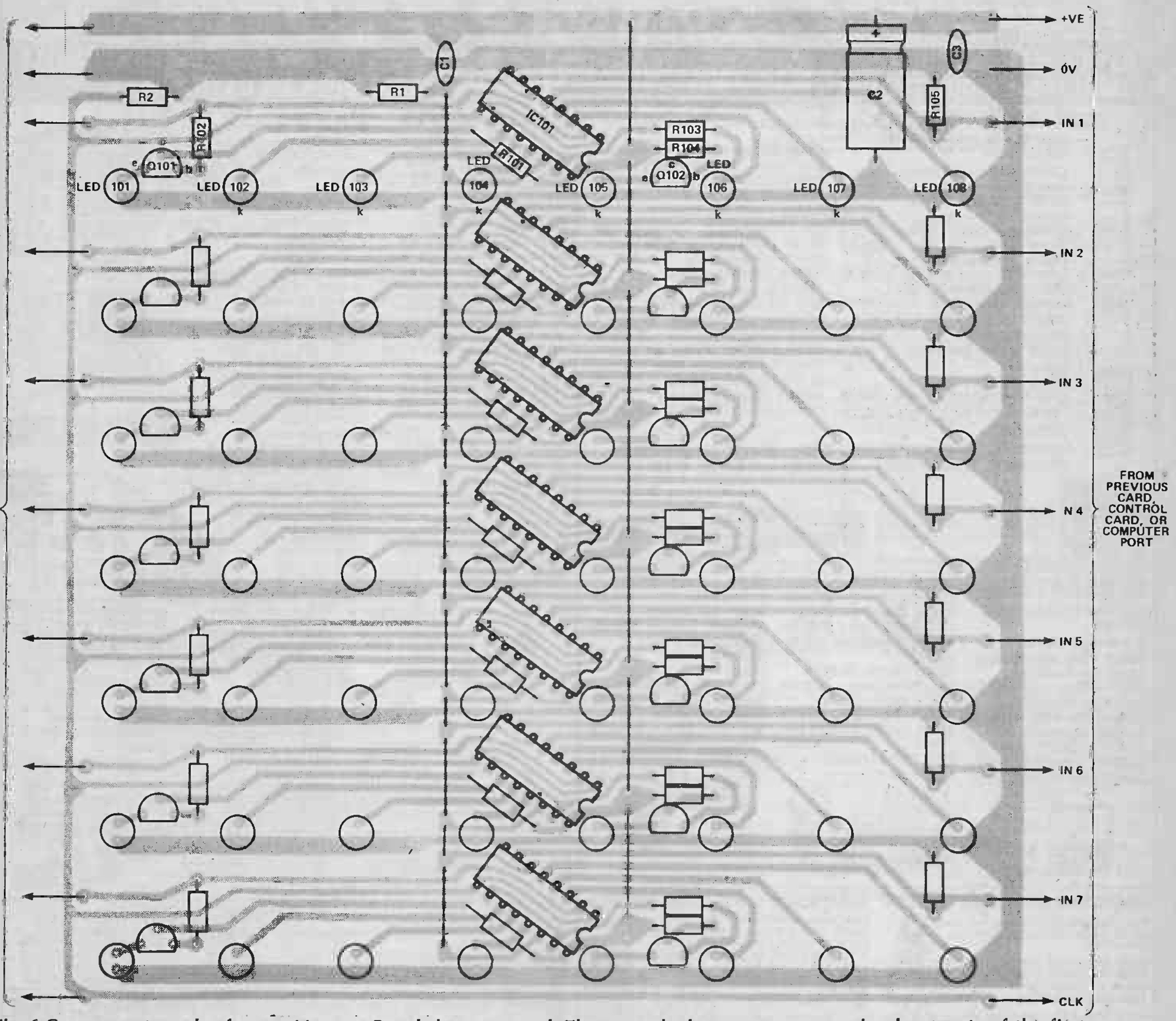


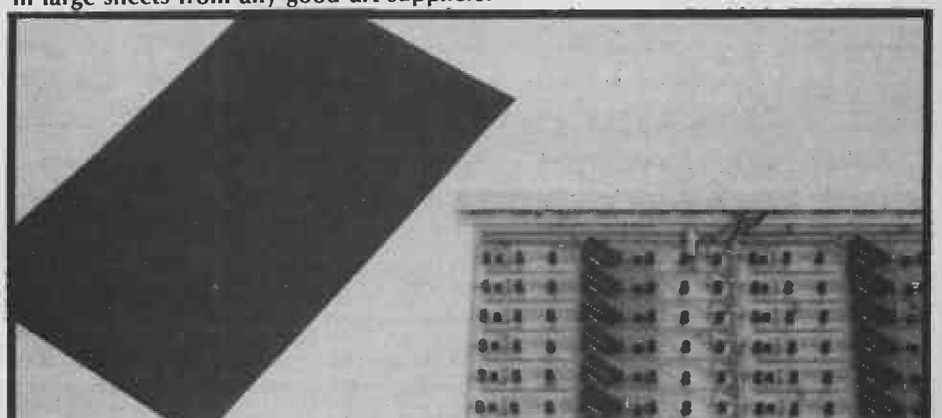
Fig. 6 Component overlay for one Message Panel character card. The unmarked components are simply repeats of the first row.

PARTS LIST

Resistors (all ¼W, 5%)	
R1	100k
R101, 104	680R
R102, 103	22k
R2, 105	1M0
Capacitors	
C1, 3	1n0 ceramic
C2	220u 25V axial electrolytic
Semiconductors	
IC101	4015B
Q101, 102	BC184L
LED101-108	high efficiency 5 mm red LEDs (L531D — see Buylines)

Miscellaneous
PCB (see Buylines): aluminium extrusion for shelving systems; red filter plastic.

The red filter plastic used to improve the contrast of the display should be obtainable in large sheets from any good art suppliers.



ETI

DIGEST

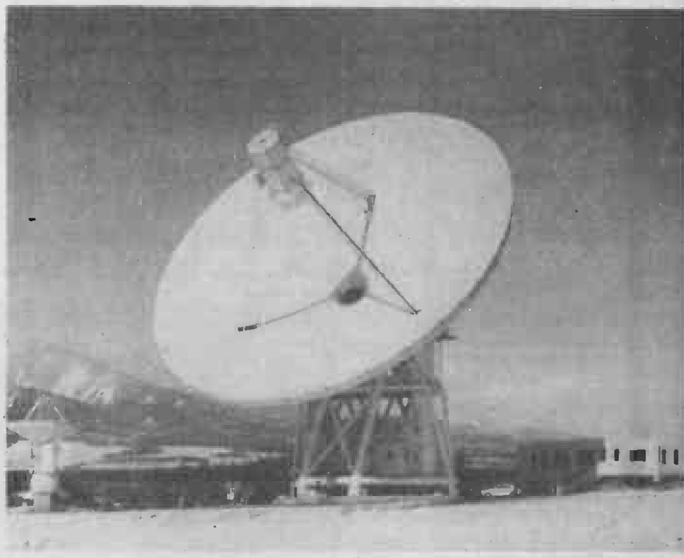
A Nip In The Airwaves

Mitsubishi Electric Corporation recently completed installation of a large-scale radio telescope boasting the world's highest precision on Nobeyama Heights, Nagano Prefecture, Japan. The fabrication of this radio telescope for the Tokyo Astronomical Observatory of the University of Tokyo commenced in April 1978 and cost a total of 10 billion yen. The world's largest movable radio telescope today is the one at the Max Planck Laboratory in Bonn, West Germany, with a parabolic antenna of 100 m diameter. Though the Japanese radio telescope is not as large as the one in Bonn, it claims the world's greatest precision and performance in terms of picking up milliwaves.

The Nobeyama Heights radio telescope consists of a parabolic antenna measuring 45 m in diameter, 53 m in height, and approximately 700 tons in weight; five parabolic antennas, each measuring 10 m in diameter and approximately 35 tons in weight; a receiving apparatus and a data processing system. The five parabolic antennas making up the interferometer freely move on 30 foundations established on approximately 600 m base lines running north-south and east-west, giving a resolution of one second of arc and providing a clear radio wave image.

The high precision and performance of the radio telescope was achieved by the adoption of a number of the latest technologies such as a newly developed homologous design method which limits the discrepancy in the point of parabola of parts to less than 0.2 mm, which is pretty damn accurate, a master collimator which realizes a direction accuracy of 1/1000 degree, and an optical system which makes possible the on-ground observation of radio waves collected by the main telescope reflector with a beam transmission system employing a maximum of 15 reflex mirrors.

Starting full-scale observation from April 1982, the telescope, which can observe millimeter waves arriving from several billion light-years away, is expected to contribute greatly to our knowledge of the origin of the universe, the birth of stars, and the evolution of our galactic system.



The Silicon Sieve

It's well known that the USA possesses a technological lead over the USSR, so it's hardly surprising that the Russians are keen to close the gap, by fair means or otherwise.

Amongst the fair means employed are the normal communication channels of the academic world. Besides conferences and scientific journals, research scientists rely heavily on informal contacts — and it's this that the CIA objects to. Scientists find it very useful to discuss their research topics with other scientists working in the same or related fields, to cross-fertilise ideas. Because it's impossible to define which areas of scientific research are defence-related and which are not, the CIA regards such conversations as a security risk; but to the scientists, it's a vital part of their work, without which they would become stale. The American government is trying to limit the access of foreign nationals to unpublished research, and scientists in universities are strongly defending their academic freedom.

Another less legitimate means that the Soviet Union uses to obtain high technology is by buying high technology items through the back door. Because the USA has banned the export of such items to the USSR, this has to be done through several intermediary stages, involving export to a friendly country and subsequent re-export to the USSR. Thus computers for use in West Germany turn up on a test bench in the USSR being dismantled to see how they work.

To try and stem this unwelcome trade, the US government has mounted a special security operation that has so far blocked nearly 500 shipments of technical equipment. This operation was first begun in October 1981, and though the volume of goods apprehended is high, it is impossible to gauge what degree of success it represents — no one knows about the shipments that get through.

Silicon Valley is an obvious target for out-and-out industrial espionage, and it isn't just the Soviets that are interested. Employees of several Japanese companies have been caught red handed. Factories and offices in Silicon Valley are built like university buildings, and these make rigorous security a nightmare to implement. In any case, there would be a lot of resistance from the staff of the companies to any noticeable tightening up on their freedom of movement.

The CIA believes that there are several hundred foreign agents operating in the region, a large proportion of them Russian and well organised. Their main targets are believed to be VLSI and in particular VHSIC technology, as well as large scientific computers such as Cray-1 and the liquid gas-cooled computers presently under development. Computer software is also believed to be a target as well.

Fuller report in Electronics Weekly, July 28th, 1982.

Ed Transplant

This issue of ETI is the first under the auspices of Dave Bradshaw, the new editor of the magazine. Dave's appointment follows the promotion of Ron Harris to Managing Editor, a post where he'll be worrying about things beyond the ken of us mere editorial mortals (the things some people will dor for a bigger desk . . .). Dave has experience in both electronics and journalism; he did a stint researching and teaching at university and left Handyman Which? to join us at Argus. Thus he's eminently qualified to take over the bridge of ETI, and, not content with keeping us the best, he'll be taking ETI where no magazine has gone before. So stick with us — and enjoy.

Machine Mate

A formidable new chess team has been formed by nine chess champions — Chess Champion Mark V chess computers, that is. The 'team' made its debut at the recent John Plank Travel Invitation Team Tournament in Bournemouth, and came fourth after winning five of the nine matches against human opponents; one of whom was a (probably slightly embarrassed) British Chess Federation assistant coach, Richard Holmes. Vulcan Electronics intend entering other conventional competitions throughout the country. Purveyors of the Chess Champion range, Vulcan can be found at 200 Brent Street, Hendon, London NW4 1BH.

DESIGNING MICRO SYSTEMS PART 3

A computer never forgets — provided the information is stored in ROM. Owen Bishop explains the different types and the different applications.

When the structure of a computer was described in Part 1, 'memory' was considered simply as a section of the circuit responsible for storing information (instructions or data). Part 2 showed how this information is in the form of a sequence of binary code groups, each usually containing eight bits (one byte).

The first point to consider is why a computer needs memory. Although the MPU has internal programming which makes it perform a given operation (such as adding together the contents of two registers) when it receives a machine code instruction on the data bus, there is nothing *inside* it to tell it what operation it is to perform next. The operations it performs automatically are very simple ones. Adding together two single-byte numbers is an example already given. Other examples are incrementing a number by 1, decrementing a number by one, transferring the contents of one register to another register, logically ANDing the contents of two registers and so on.

Simple Sums, Complex Sequences

It takes a fairly long sequence of these fundamental operations to perform even the simplest of calculations. For example, to add two numbers which are already stored in memory and to display the result on the monitor screen, the MPU has to:

- Read one number, already stored in memory location X, and store it in its accumulator
- Read the other number, stored in memory location Y, and add it to the number already in the accumulator
- Refer to a table of data already stored in memory to convert this number to its equivalent in the ASCII code. The ASCII code (of which more will be said in a later issue) is a special code used in the majority of computers for representing letters, numbers and punctuation marks in binary form. It takes the MPU several operations to find the ASCII code, and then it has to
- Find out in which screen position the answer is to be displayed and work out which byte of memory the code group must be stored in to achieve this. Finally it must
- Transfer the ASCII group along the data bus to that byte of the video memory, so causing the answer to be displayed on the screen in the correct position.

The procedure above may sound complicated but it is a gross oversimplification of what the MPU has to do. For instance, we have assumed that the two numbers are stored as single bytes, but a single byte can take values only from 0 to 255. Most micros store integers as double-bytes (allowing values from −32768 to +32767). They require four bytes for floating-point numbers (seven-figure precision) or eight bytes for 16-figure precision. To add two such numbers together, the MPU must work with the pairs of bytes in turn (one from each number), adding in any carry-over digit from one addition to that of the next higher pair of bytes. It is clear that even the simplest of mathematical operations requires a long sequence of operations by the MPU. Since the MPU can accept and act on only one instruction at a time, the sequence of instructions is set out in a **program,** which is held in **memory.**

ROM And RAM

At this stage we must distinguish between the two kinds of memory that may be used for instructing the MPU. In physical terms, both kinds of memory consists of arrays of integrated circuits, as will be described later. When you type a program into the computer, or when you load a program from a cassette tape or a floppy disk, it is stored away in a part of **Random Access Memory** (RAM for short). We say it is 'written into' RAM. The information is stored in memory cells (bit-storing sub-circuits), hundreds of thousands of which go to make up the circuitry of each RAM IC. With RAM you can, if you wish, supply the MPU with a different program every time the computer is used. When a program is run the MPU 'reads' the program from RAM. When you switch off the computer, or type NEW, the program is lost. RAM will be the subject of next month's article but, to sum up its main features, we can say its contents may readily be changed, and it loses its contents when the power supply is cut off.

By contrast, the contents of **Read Only Memory** (ROM, for short) cannot be changed or, if changeable, can be altered only as the result of a special procedure, and are not lost when the power supply is cut off. The fact that the contents are not readily changeable is reflected in the name 'Read Only'. In other words, this kind of memory is intended only (or primarily) to be read from, not to be written into.

Kinds Of ROM

Obviously, there must be a way of writing instructions into ROM, otherwise it would contain no instructions and would be totally useless. There are several different types of ROM with different ways of writing instructions into them. To begin with we will look at the type known as the **mask-programmed** ROM.

Each memory cell (each bit) is programmed at the manufacturing stage. Typically, the cell consists of a transistor with its gate either connected to ground or open-circuit. A connection to ground means that the output from the cell is 1; open-circuit gives an output 0. Before the ROM is made, the program which is to be stored in it is very carefully tested to ensure that it is free from error. The masks used for making and linking the components on the slice of silicon are drawn out accordingly. Cells which are to store a 1 have the gate of the transistor grounded. When the ROM is in use and the MPU addresses a particular cell by applying the appropriate combination of voltages to the address terminals of the ROM IC, the cell's output is gated to one of the data lines. This output may then be read by the MPU. Thus the program is permanently built in to the structure of the IC and cannot be altered after manufacture.

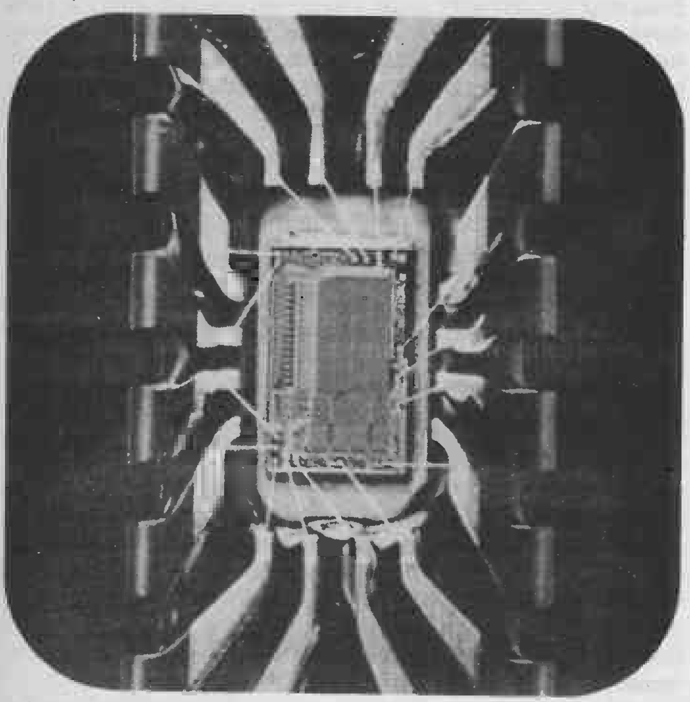
High Volume Equals Low Cost

As might be expected, this procedure is an expensive one, due to the high cost of preparing the special masks. Only if hundreds or thousands of ROMs are to be manufactured with exactly the same program, does the cost fall to a reasonable level. This is the type of ROM generally used for holding the monitor program of a computer and perhaps a resident language, as explained later. Mask-programmed ROMs are made with capacities between 1 kilobyte and 8 kilobytes.

The advantage of the mask-programmed ROM is that once the program has been finalised it is possible to manufacture identically programmed ROMs in large quantities very cheaply. For prototyping and for applications in which it is known that only a few ROMs with a given program are likely to be required, we need a ROM that does not depend on mass-production for cheapness. For this purpose we use a different type of IC, known as a programmable ROM, or PROM for short. There are several kinds of PROM, as will now be described.

Fusible-link PROMs

In a typical version of this kind of PROM the gate of the transistor of each cell is joined to ground by a fusible link. This is a connection which can be destroyed by passing a high current through it. To begin with, all transistor gates are grounded so all the cells in the PROM are set with output 1. When a particular cell is addressed by putting the appropriate combination of inputs on the address lines of the IC and a high voltage is applied to a special terminal of the IC, the link is 'blown'. From then on, that cell gives a 0 output when addressed. Fusible-link PROMs are usually programmed by special electronic PROM programmers which may operate under the control of a computer. The controlling computer holds the program which is to be written into the PROM and coordinates the processes of applying addresses and 'blowing' the links. Once the PROM has been programmed it can not be reprogrammed, for it is possible only to convert 1 to 0, but not 0 to 1. If only a part of it has been programmed, the remainder still being all 1s, the remainder can be programmed on a later occasion. An example of a fusible-link PROM is the Intel 3624, which stores 512 bytes ($\frac{1}{2}$K).



A photomicrograph of a typical mask-programmed ROM chip.

The Ubiquitous EPROM

An erasable PROM can be erased and reprogrammed. The most frequently used EPROM is that which is erased by exposing the chip to ultraviolet light. You can recognise this kind of IC by the window of quartz, through which the chip itself can just about be distinguished as a greyish object about 4 or 5 mm square. Quartz must be used rather than glass, since glass is not transparent to ultraviolet radiation. The UV-erasable EPROM stores information by making use of the extremely high electrical insulation properties of silicon oxide. Insulating layers can be readily formed on the surface of the substrate, simply by oxidising it. In each memory cell, the gate of the transistor has a control gate situated close to it, but separated by an insulating layer (Fig. 1). The gate itself is left unconnected and floats with whatever charge it may acquire.

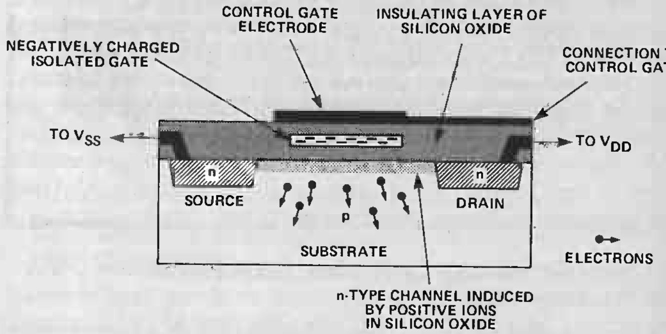


Fig. 1 Diagram of a memory cell in a UV-erasable EPROM. The gate is an N-channel depletion-type MOSFET; here the gate is shown with its negative charge depleting the N-type channel by repelling the electrons in it.

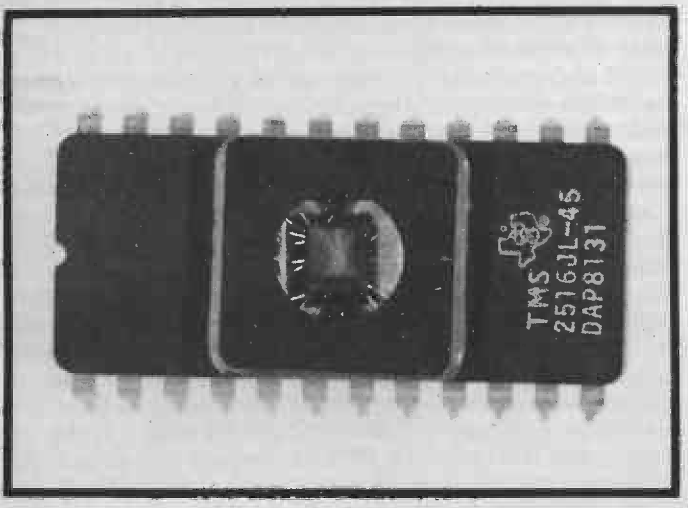
After manufacture, the gate has no charge, so each cell gives a '0' output. In programming, a high voltage (about 25 V) is applied to the control gate (Fig. 2). Some electrons in the control gate gain sufficient energy to cross the insulating layer and charge the gate of the transistor. Once the gate has been charged, the charge remains for decades, and the cell gives a '1' output. The only way of rapidly removing the charge is to expose the gate to a highly energetic radiation, such a short-wave ultraviolet radiation. This is making use of the photoelectric effect.

A Wavelength That Wipes

The amount of energy carried by a photon of radiation depends on its wavelength; the shorter the wavelength the greater the energy. In the UV range, only short-wave UV photons carry enough energy each to dislodge an electron from the floating gate. Photons of visible light and UV of longer wavelength each carry too little energy so they have no effect whatever. Radiation of shorter wavelength, such as X-rays and gamma rays (which are emitted by certain radioactive elements and produced by a nuclear explosion, for example) are also able to erase EPROMs though these radiations are not in normal use for erasing!

After an exposure to short-wave UV lasting a half an hour or more, the gates of all cells on the IC become discharged. The EPROM is then ready to be programmed again. In this way it has a great advantage over the fusible-link PROM and is widely used in microprocessor systems. Although the EPROM has to be removed from the computer and placed in a special EPROM programmer device (which may be under computer control) the programming, erasing and reprogramming of EPROMs is a straightforward matter. Naturally, it is preferable for the program to be correct to begin with and to have no bugs but, if an error *is* discovered in the program, it can be replaced by a corrected version in an hour or so.

An EPROM is a PROM which is read from most of the time but which can be written into occasionally. The operation of writing generally takes rather longer than the reading operation. For these reasons some people refer to EPROMs as read-mostly memories (RMMs).



A typical EPROM. The silicon ROM chip can be seen under the quartz window.

EEROMs And EAROMs

When an EPROM is erased the exceedingly small size of the memory cells makes it impossible to pick out any one cell or group of cells for treatment. It is necessary to erase the whole EPROM and program it all again. There are other kinds of PROM which can be erased electrically, known as EEROMs and EAROMs. The EEROMs, or electrically erasable ROMS are similar to EPROMs in that the whole array of cells must be erased, but erasing is achieved by passing a current through the device. EAROMs, or Electrically Alterable ROMs allow us to discharge the gate by a signal applied to the control gate. In this way we can alter any one or more memory cells without affecting the state of the others.

An example of an EAROM is the General Instruments ER3400. Most of these devices employ NMOS transistors and, while they are relatively expensive at present, their cost is beginning to fall, and they will soon be very competitive with the UV-erasable ROMs. It takes so little time to erase and reprogram these devices that it is feasible for their programming to be carried out while they are still plugged in to the computer circuit. The usual power supply at +5 V is required for reading and supplies at other voltages such as −12 V and −30 V are required for programming. We now have the possibility of the computer with appropriate power supplies being able to alter its ROM during the course of running a program; the distinction between ROM and RAM becomes more clouded, though there remains the fact that ROM is permanent (if we want it to be) while RAM is not.

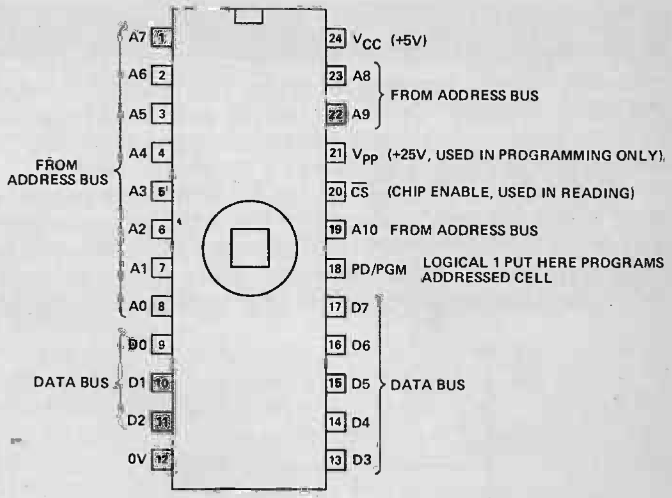


Fig. 2 The pin connections of the 2716, a commonly-used 2K EPROM. During programming the data bus is used to input the required bytes.

Using ROM

Before going on to discuss how ROM is used, we will discuss *why* ROM is needed in a computer. Why not just use RAM which is so flexible and can be readily altered at will? To answer this, let us follow the sequence of events when a computer is first switched on. First of all the MPU is reset. This is usually done automatically by a capacitor connected to the reset input, so that the voltage there is held low for a fraction of a second after all other inputs have reached 5 V (Fig. 3). In addition, most computers have a reset button to allow manual resetting — this is particularly useful if the computer latches up in some otherwise interminable cycle of operations, as it may well do if there is a bug in the program.

When the reset input is made low, either at power-up or by manual resetting, one of the most important results is that the program counter of the MPU is set to a fixed value. In the Z80 and 8505 the program counter is cleared to address 0000. The first thing that the MPU will then do is to try to read an instruction from memory at address 0000. We must make sure that there is an instruction there for it to execute, otherwise it will never be able to do anything. It will be no good typing in instructions at the keyboard or trying to load them from tape or disk. Until the MPU has been told to scan the keyboard for input or to register the signals coming in at the tape or disk sockets you will be unable to communicate with it. What it needs *as a minimum* is a short program to allow it to acquire instructions through the keyboards, or from tape or disk, and store these instructions in RAM (they cannot go in ROM, of course, because ROM cannot be altered). ROM is essential for holding the initialising program which tells the MPU how to get information from the keyboard, tape or disk.

Putting The Boot In

This kind of short program which enables the MPU to get started on its more important tasks is called a **bootstrap program.** It helps the MPU pull itself up by its bootstraps! Since such a program must already be in the computer from the moment power is switched on, the obvious course is to place this program there permanently in ROM. Most computers have additional ROM programs to instruct the MPU how to do other kinds of routine jobs, such as send output to the display. Quite often a message such as 'APPLE II' or 'MEMORY SIZE?' is placed on the screen when the computer is switched on. The program to do this is held in ROM. The complete program may occupy a few kilobytes of memory. Such a program is generally called a **monitor program.** This is another use of the word 'monitor', the name usually given to a purpose-built computer video display (as opposed to a domestic TV set being pressed into service as a computer display).

The monitor program is usually written in machine code (see last month's article), for this is the most compact way of instructing the MPU and allowing it to operate at its maximum speed. Most computer users prefer to communicate with the MPU by using a high-level language,

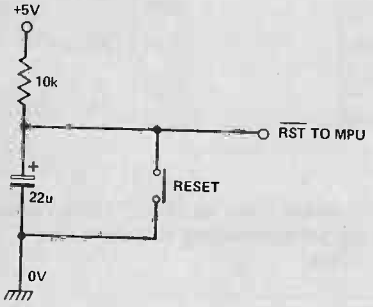


Fig. 3 A simple resetting circuit.

such as BASIC. MPUs do not understand BASIC, so a program is needed to interpret programs written in BASIC and convert them to machine code. Then the MPU can understand what it must do. The interpreting program (or interpreter) can be loaded from tape to disc into RAM but, since such a program is likely to be required every time the computer is used, it is more convenient to hold it in ROM. Thus the ROM of a microcomputer may have, say, 12K of ROM which holds all the routines (in machine code) for converting BASIC commands into the corresponding op codes.

When buying a microcomputer it is essential to find out whether you need to buy BASIC on a disc and load it every time you want to use it, or whether the BASIC is resident in ROM. Usually the memory space quoted for a computer is the amount of RAM it has. A computer which is listed as having 48K will allow you to use almost the whole of that for your programs if its BASIC is in ROM. On the other hand, if the computer has 56K but no resident language, the language may use up 12K of that space when loaded in RAM, leaving you with only 44K for your own programs.

A Change Of Character

Another use for ROM is to hold tables which are to be frequently used by the computer. A good example is the 'character generator' ROM. Before it can put a character on to the screen the MPU must find out exactly what pattern of dots are required to produce the letter, numeral or symbol that is to be displayed. These patterns are held in the character generator ROM. The MPU reads the appropriate pattern from the ROM and sends it to the video area of RAM, causing the character to be displayed.

It is feasible to manufacture several different character generator ROMs, each programming a different selection of characters. There can be different type-faces, or the selection of letters and symbols can be chosen according to the country in which the computer is to be used. For example, Video Inc. manufacture a series of such EPROMS for Apple II including the French, German, Spanish and Katakana (Japanese) alphabets, and one holding mathematical and Greek symbols.

Another type of plug-in ROM which is widely used is that which holds a complete games program, educational program or utility program. Instead of loading the program from tape or disk, the user simply plugs in a module containing a pre-programmed ROM. The Atari and Tandy TRS-80 Color Computer are examples of machines with this facility, as are many of the more specialised TV games machines.

Addressing Memory

We have often referred to the MPU addressing a given byte in memory at a particular address, without giving any indication of how this is done. Let us look into this in a little more detail. As an example, consider a ROM (it might be a regular mask-programmed ROM or some type of PROM) which stores 4 kilobytes. Each bit of these 4096 bytes is represented by a memory cell. This very-large-scale integrated circuit (VLSI) therefore contains 32768 memory cells, each consisting of a transistor which is set on or off depending upon whether it corresponds to a 0 or a 1. It also contains the logic circuits required to ensure that when any one of the 4096 possible combinations of voltage levels (the 4K addresses) is put on the lower 12 lines of the address buses (lines A11 to A0), then the eight bits of information stored by the corresponding eight transistors will be gated on to the eight lines of the data bus.

The extreme complexity of such a circuit is difficult to imagine, yet it is commonplace on the computer circuit board. To accommodate a monitor program and a resident language we may need three such ICs, giving a total ROM memory of 12K. Suppose that this is to run from the very bottom of the computer's memory (from address 0000 onwards). The addresses corresponding to the three ICs will be as shown in Table 1. From the binary address it is clear that the lower 12 address lines are responsible for differentiating between all the addresses held in a single ROM. The state of the upper four address lines (A15 to A12) tell us which of the three ROMs is to be addressed at any particular time. Thus the address 4295 (10C7 in hex) appears on the bus as:

0001 0000 1100 0111

and refers to ROM 1. The address 8391 (20C7 in hex) appears on the bus as:

0010 0000 1100 0111

and is located in ROM 2. All three ROMs receive the signals on lines A11 to A0. How can we ensure that only ROM 1 responds to the address 10C7, while only ROM 2 responds to 20C7?

The outputs of the roms to the data bus are **tri-state** outputs. That is to say they normally present a very high impedance; they are virtually disconnected from the bus and are incapable of either sending or receiving signals. Each ROM has one (more in some types) special input known as **chip select** ($\overline{\mathrm{CS}}$). The bar over the $\overline{\mathrm{CS}}$ indicates that this is an active-low input. When the $\overline{\mathrm{CS}}$ input is made low, data outputs go to a low-impedance state and whatever data is present on the set of cells currently being addressed is put on to the data bus. Fig. 4 shows how we control which ROM is to be active at any given time.

Go Low To Go

The function of the circuit is to enable one ROM at a time by making its $\overline{\mathrm{CS}}$ input go low. The ROM to be selected is determined by the signals present on the upper four address lines and on a control line which indicates when the MPU is ready to read data. In the Z80 this is the $\overline{\mathrm{MREQ}}$ line, which is active-low. The 74LS138 is a 3-to-8-line decoder which is typical of the ICs used for decoding address lines in computers.

TABLE 1

ROM NO.	ADDRESS RANGE DECIMAL	HEXADECIMAL	BINARY
0	0 to 4095	0000 to 0FFF	0000 0000 0000 0000 to 0000 1111 1111 1111
1	4096 to 8191	1000 to 1FFF	0001 0000 0000 0000 to 0001 1111 1111 1111
2	8192 to 12287	2000 to 2FFF	0010 0000 0000 0000 to 0010 1111 1111 1111

Lines A12, A13 and A14 go to the A, B, and C inputs of this IC. Their states are treated as a three-bit binary input. Outputs Y0 to Y7 are normally high but, provided that the IC is enabled, one of the outputs is low at any one time, depending on the binary input to A,B,C. Thus when A is low, B is high and C is low, this corresponds to 010 (equivalent to decimal 2), and output Y2 goes low. This makes the $\overline{CS}$ input of ROM 2 low, so ROM 2 is enabled while the other ROMs remain disabled in the high-impedance state. The location in ROM 2 which is to be addressed is then determined by the state of the other (lines A11 to A0) of the address bus.

The decoding of inputs A, B and C as described above takes place only if the decoder itself is enabled. It has three enable inputs, G1, G2A and G2B. To enable the chip, G1 must be high and either G2A *or* G2B must be low. You will notice the convention on the drawing that small circles are drawn at G2A and G2B to indicate that they are active low. The outputs also have these circles, for the same reason.

There are several possible ways of using the enable inputs to make sure that the chip is enabled only when address line A15 is low and the $\overline{MREQ}$ line is low too. The solution shown here is to NOR A15 and $\overline{MREQ}$ together and feed the result to G1. This makes G1 high only if both A15 and $\overline{MREQ}$ are low. Inputs G2A and G2B are not used and are grounded.

Let us sum up the procedure of reading from ROM. In order to address any particular cell of ROM, the MPU puts its address on the bus. In the example given, the address will be received along lines A0 to A11 *in all three ROMs.* The states of lines A12 to A14 are to be decoded by the 74LS138 and line A15 must be low to allow the decoder to be enabled. Then the MPU takes its $\overline{MREQ}$ output low to indicate that it wishes to read data. This makes the NOR gate output go low, enabling the decoder. One of its outputs then goes low, enabling *one* of the ROMs. The ROM so addressed puts the data on the bus and this is read by the MPU.

The procedure outlined above must be carried out according to a strict time schedule. For instance, if the decoder acts too slowly, the MPU may be trying to read data before it is there. Some mention of this problem was made in Part 1, and we shall discuss it again in connection with RAM, next month.

ROM At The Top?

Readers who have taken the trouble to look at the circuit diagram of a computer and compare it with Fig. 4 may find that the ROM of their computer does not appear to be

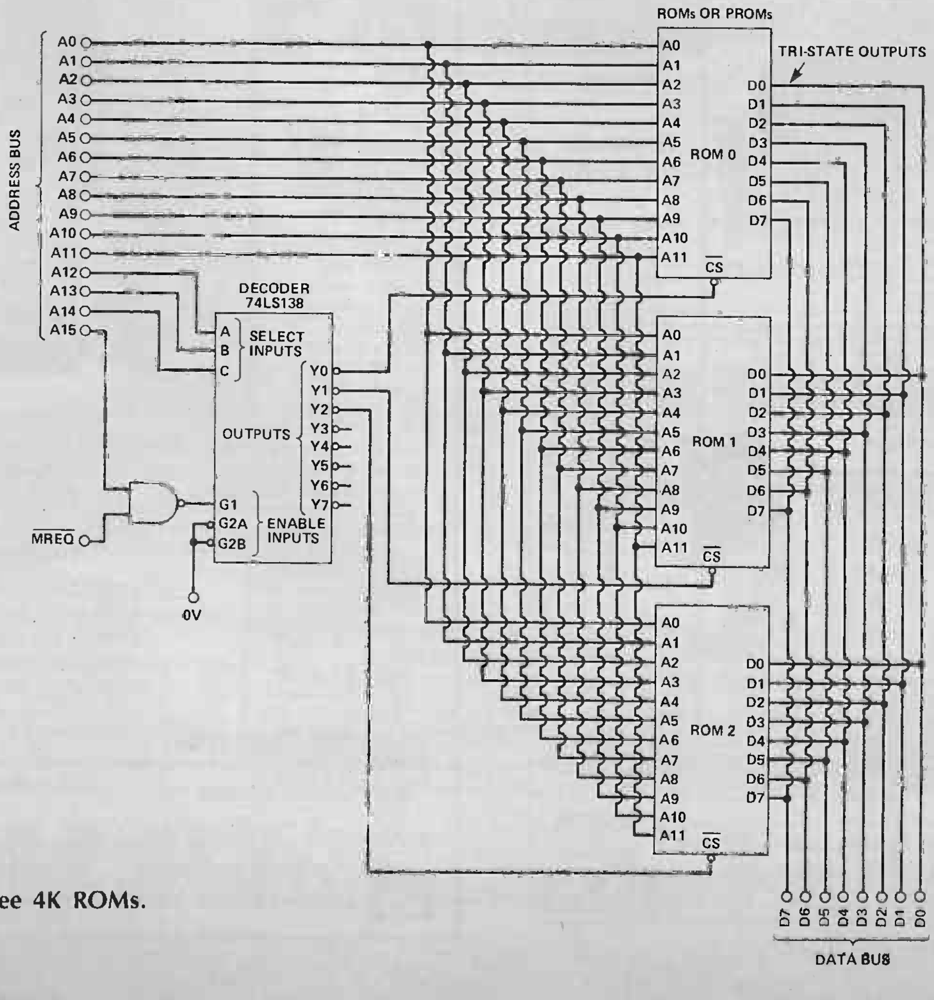


Fig. 4 Addressing three 4K ROMs.

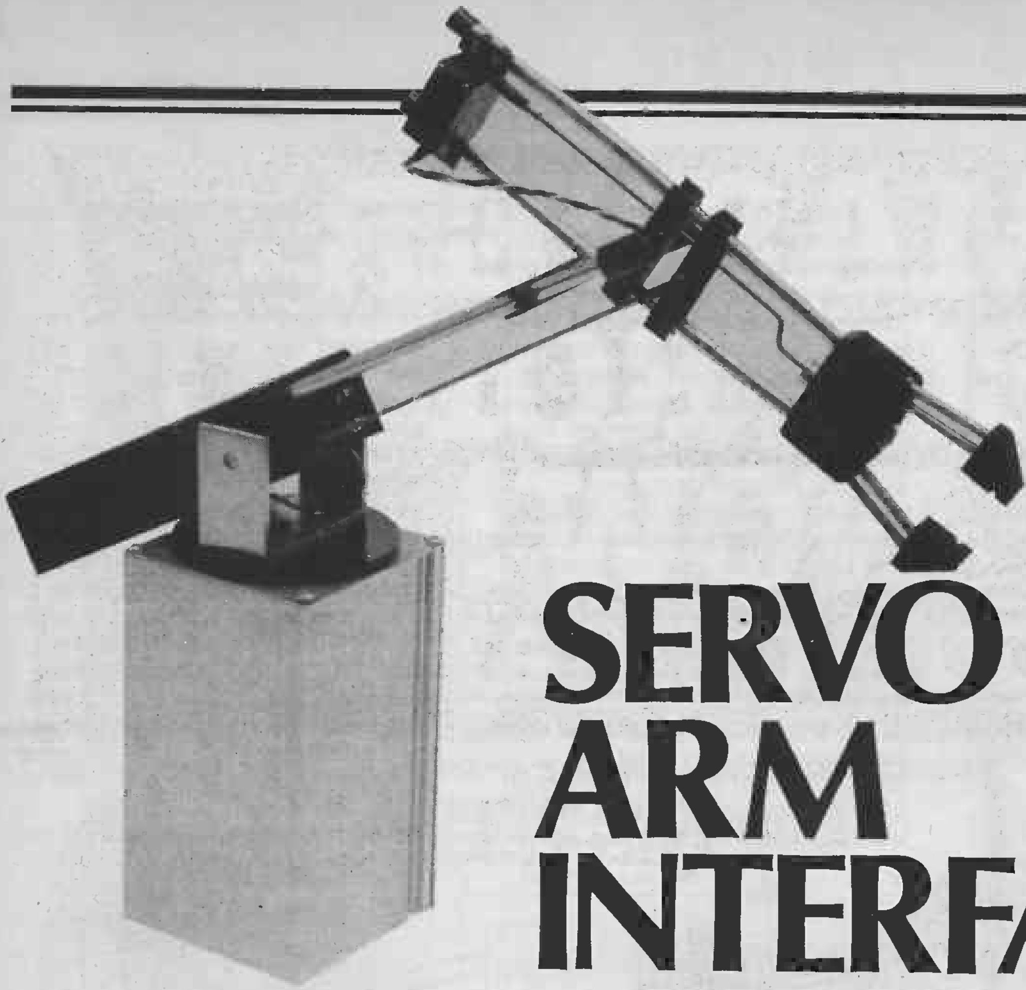
decoded to the low addresses in memory. This is the case if the computer concerned is based on the 6502 MPU. Unlike the Z80 and several other MPUs, the 6502 does not begin reading its program at 0000 after being reset. The 6502 has the special feature of **zero-page addressing;** this means that addresses in the range 0000 to 00FF can be addressed by using the lower byte only (00 to FF). This greatly simplifies and shortens programs, making this area of memory a very useful place in which to store frequently referred-to variables and tables. To take advantage of this facility, this part of memory must be allocated to RAM. Consequently, it is better if ROM is located at the top end (higher addresses) of memory instead. When the 6502 is reset, it first reads the two bytes which are stored at FFFC and FFFD, addresses almost at the top of memory. It is essential to place ROM so that it covers these addresses.

Memory cells FFFC and FFFD in ROM contain the two bytes which are the address of the beginning of the monitor program. In the Apple II with the Autostart ROM, for example, these bytes are 62 and FA, respectively. The 6502, having read these two bytes, sets its program counter to the address they indicate (FA62 in this example) and then goes to that address to begin reading and executing the monitor program.

Integrating ICs

Nowadays there is a move toward reducing the number of ICs required in computer systems. This is particularly important for special-purpose computers that are to be used in control applications, such as those in washing machines or video-recorders. The program required may be relatively small (perhaps only 2K or 3K) so there is no reason why the ROM should not be accommodated on the same slice of silicon as the MPU. If we have ROM, why not have RAM as well and any other useful devices such as input/output ports and timers? A good example of this approach is the Zilog Z8 'computer-on-a-chip'; a similar device is the Mostek MK3870. The Z8 not only has an MPU but also 2K of ROM, 128 bytes of RAM (enough to use as a 'scratch-pad' to hold temporary data), four eight-bit I/O ports, two counter/timers and an asynchronous serial interface. The ROM in the Z8 has to be mask-programmed, so this IC is not one that the hobbyist is likely to be using. The professional can obtain a version of the Z8 or the MK3870 with an EPROM mounted on it in piggy-back style. This can be programmed during the course of development and after all has been settled, the final program can be mask-programmed into the internal ROM of the production version.

A special version of the Z8, known as the Z8671, has the ROM pre-programmed with a Tiny BASIC interpreter as well as its monitor program. This can be used as the basis of a simple computer system. It has 144 bytes of RAM for use as a scratch-pad, but it can address up to 124K blocks of external of RAM or ROM for the storage of programs. This version with its general-purpose BASIC in ROM has a wider appeal than custom-programmed versions so it can be manufactured in quantity. Prices are falling and already several development boards are on sale which feature this IC. The phrase 'chips with everything' can now be taken to mean 'chips with everything on them'!



SERVO ARM INTERFACE

Run your servo-driven models under computer control or give your robot arm some muscle power — our ingenious interface board is cheap, simple and versatile. Design and development by Rory Holmes.

Modern home computers are extremely versatile control devices and with the advent of Sinclair's machines are now reasonably priced and affordable. Radio control servos are another useful device that have been around for a while. Small and moderately cheap, their reliable and proven engineering is ideal for all sorts of automation projects that require controlled movement.

An easy-to-use and easily programmable interface between the two would open up a whole area of new possibilities. This is the approach we have taken to control the ETI Robot Manipulator arm, the 'muscles' of which are RC servos. Until now, though, such a straightforward interface has not been available to the home constructor. Eager to fill this gap, ETI has designed a four channel memory-mapped computer-to-servo interface.

Servos With A Smile

Our servo controller card provides seven bits of position control for each servo, a resolution of one part in 128 which is comparable to the average servo accuracy. The operation of the servo-driving system is completely static; the system can be unplugged from the computer bus and the servos will maintain their current positions, ie those that were last programmed into the position storage registers. Radio control servos all operate on a well-standardised control input known as a Pulse Width Position signal. Each output could drive any of the many RC servos available, from the tiny lightweight type to the really massive and powerful servos used on large model boats. Even the RC motor speed controllers work on the same principle and so could be controlled from our card. All the timing and sequencing for generating the four servo Pulse Width Position signals is achieved using hardware in order to relieve the computer from real-time software routines.

In this article we shall take a close look at how servos actually work and provide a detailed description of the interface circuit from both the computer bus interface side, and the hardware timing generator.

Why a memory-mapped, totally hardware-based system, you may ask? After all, the pulse signal required for a servo is fairly simple and could be generated almost directly by the microprocessor using software. But, how much more convenient for the BASIC boffins just to say

POKE SERVO1, POSITION

and know that the servo will immediately go to the position value requested and then stay there. The programmer isn't burdened with the need to time his routines around software pulse generators, or arrange for interrupt handlers to service the servo requirements.

The hardware may seem complex at first glance but in actual fact there is only about £5 worth of TTL and CMOS chips, with few other components. The system is only marginally more complex than an ordinary eight bit user port.

The Servo Principle

Radio control servos are a marvel of miniaturised electronics and mechanics, all integrated into a single control system and squeezed into a small square box. Three wires enter the box; two power lines, ground and positive (servos operate at about 4–6V), and the third is the position control signal. This signal determines the position of the output shaft which leaves the box through a ball race bearing and is capable of providing a certain amount of torque. The diagram of Fig. 1 shows the basic components of a servo and their operation as a feedback control system. The RC system relies on a now completely standardised 'pulse width position' signal. A continuous train of pulses are sent to the servo at a repetition rate of 20mS. The pulses must be between 1 to 2mS wide, and this width is varied to vary the position of the servo shaft.

The diagram of Fig. 2 illustrates these timing details. For every size of pulse there will be a corresponding position for the output shaft, ie as the pulse width varies from 1 to 2mS, the output shaft will turn from 0 to 90 degrees, say. The extent and type of output movement (linear or rotary) depends on the actual servo, but the control signal is always the same. A potentiometer coupled to the output gears is used to sense the position of the shaft, and a signal derived from this potentiometer provides feedback to 'close' the positional control loop.

The servo control electronics works in the following way: a monostable produces pulses with width proportional to the potentiometer position. These are compared to the pulse width of the position control signal. If there is a difference in the pulse sizes then 'error' pulses are produced to drive the motor and gear system in a direction to reduce the error. When the potentiometer reaches the correct position the 'feeding-back' pulses are equal to the control input pulses and the system stops.

Port To Port

A lot of the synchronising problems that would normally crop up with this sort of computer interface have been avoided by using a super-cunning device, the 74LS170 multi-access register file. Essentially, this is a small block of RAM which can be accessed from two different directions, thus allowing independent and simultaneous writing and reading, even on the same memory location! The LS170 is an open-collector version of an identical LS TTL device, the 670, containing four-by-four bit registers. The open collector version is cheaper and better suited for interfacing with CMOS, though in other respects they are the same. For about 80p they offer an interesting and elegant technique for the computer hobbyist who wants to memory map just a few bytes for controlling some 'outside-world' device.

A Universal Interface

Although the PCB has been arranged specifically for use with the Sinclair ZX81 and Spectrum buses, the computer bus interface circuitry has been designed to suit almost any type of microcomputer where the address and data busses are available. It allows great flexibility in its user configuration. In the address decoder, the use of TTL data comparators allows the address and even the control line logic levels to be individually set up using on-board DIL switches (or wire links for the economists). The multi-access registers, described above, accept and store data from the computer data bus. A data byte is written to them whenever the address decoder detects that its address has

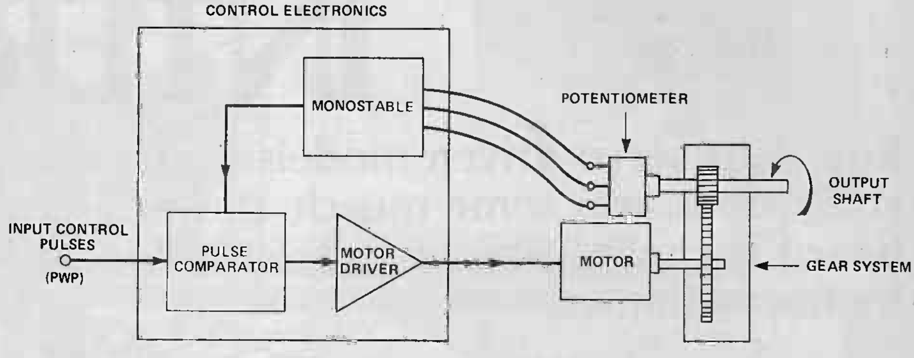


Fig. 1 Basic block diagram of a radio-controlled servo system, showing the feedback via the potentiometer and monostable.

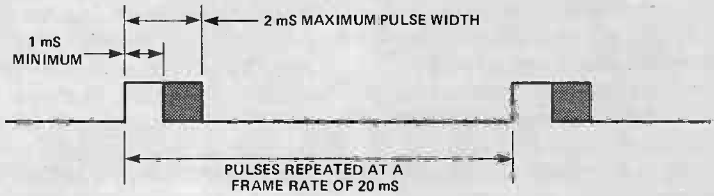
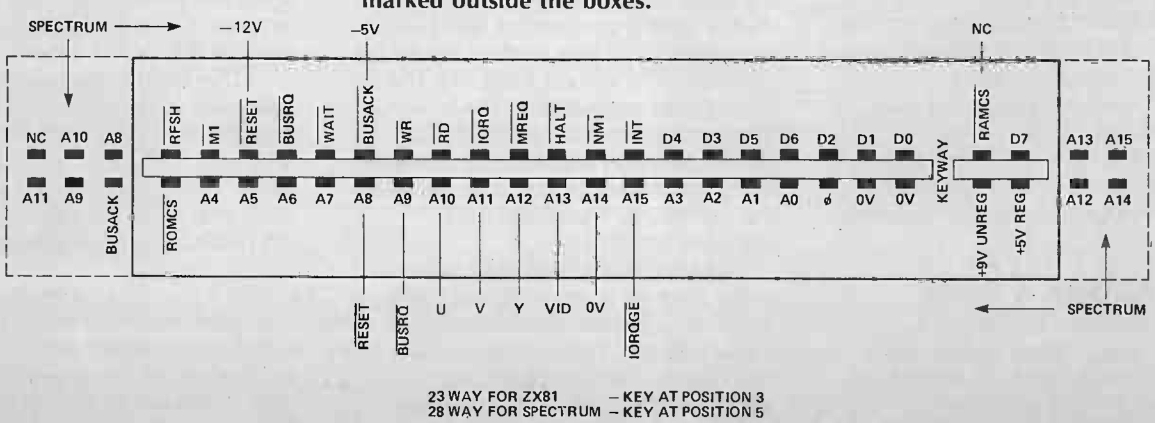


Fig. 2 Timing details for the standard pulse width position control signals.

Fig. 3 The pinout for the ZX81 edge connector is shown here inside the black rectangle. The additional pins for the ZX Spectrum connector are shown within the dotted lines, while the Spectrum signals which differ from the ZX81 are marked outside the boxes.



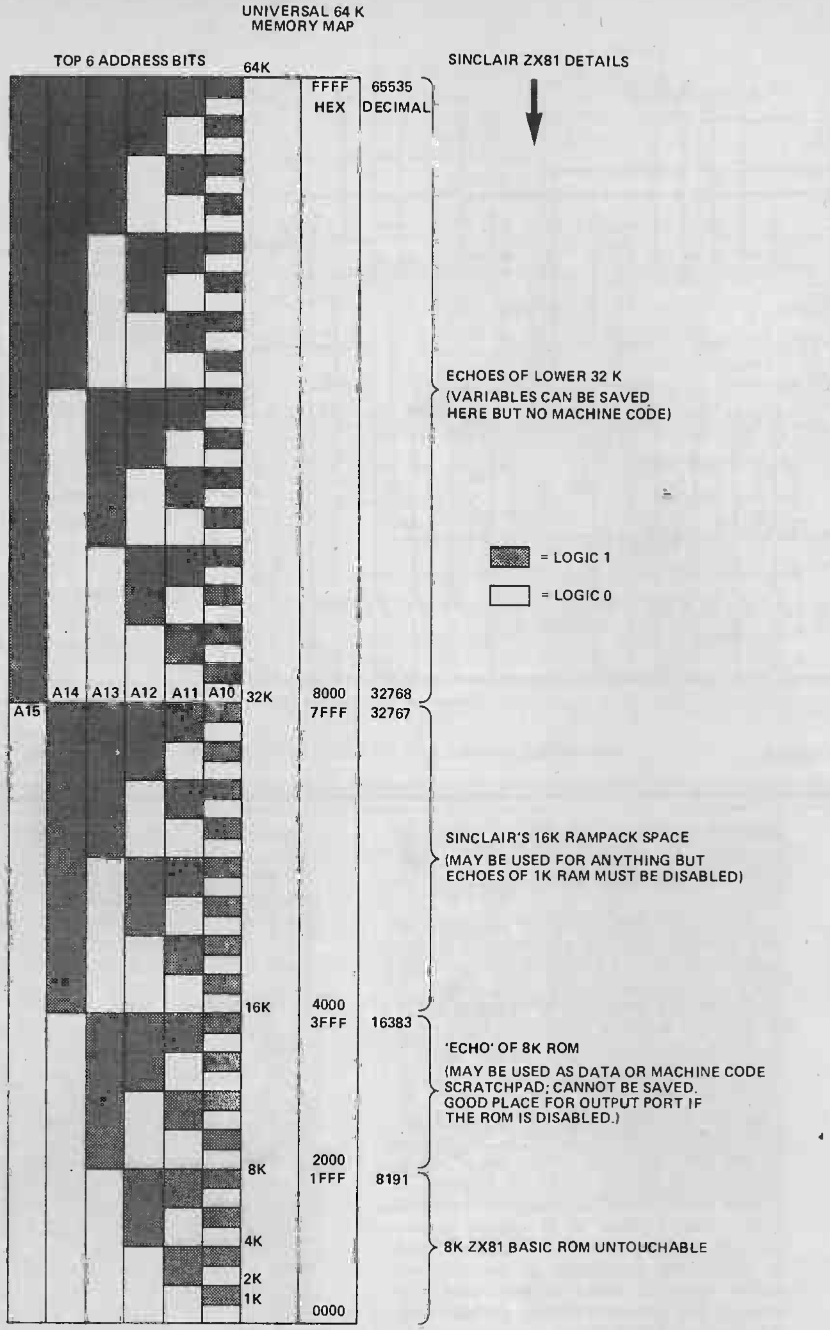


Fig. 4 Simplified memory map of the ZX81, showing some of the salient features.

been issued for a 'memory write' operation. The decoder output activates the 'write enable' input of the registers, which then latch in the current data much like ordinary memory. The 'How It Works' section gives a more detailed explanation of the actual logic.

ZX'ers

The PCB will be described next month; it has been designed to hold a Sinclair-style 23-way double-sided edge connector. This allows the board to plug directly into the ZX81 or the Spectrum, making all the required bus connections automatically. Figure 3 shows the pinout of this bus connector for both the ZX81 and the Spectrum. As can be seen, not all the pins carry the same signals, but fortunately the ones we require from the Spectrum are in the right place. Since the Spectrum's memory map is fairly choc-a-bloc and Z80 I/O instructions are provided from BASIC, we decided to use the I/O mapped output method. To the programmer the only difference is

OUT x,y

instead of

POKE x,y.

For the ZX81, a memory mapped output is used with more extensive decoding, allowing the interface to reside practically anywhere in memory except the famous 8K ROM space. Figure 4 shows a 64K memory space, illustrating the address bit logic values for each region with some salient features of the ZX81's personal map.

The two example programs written in ZX81 BASIC illustrate how the computer may be used to drive the ETI manipulator arm.

Next month we shall describe the construction and testing of the board, choosing and setting up the interface address, and some further programming techniques.

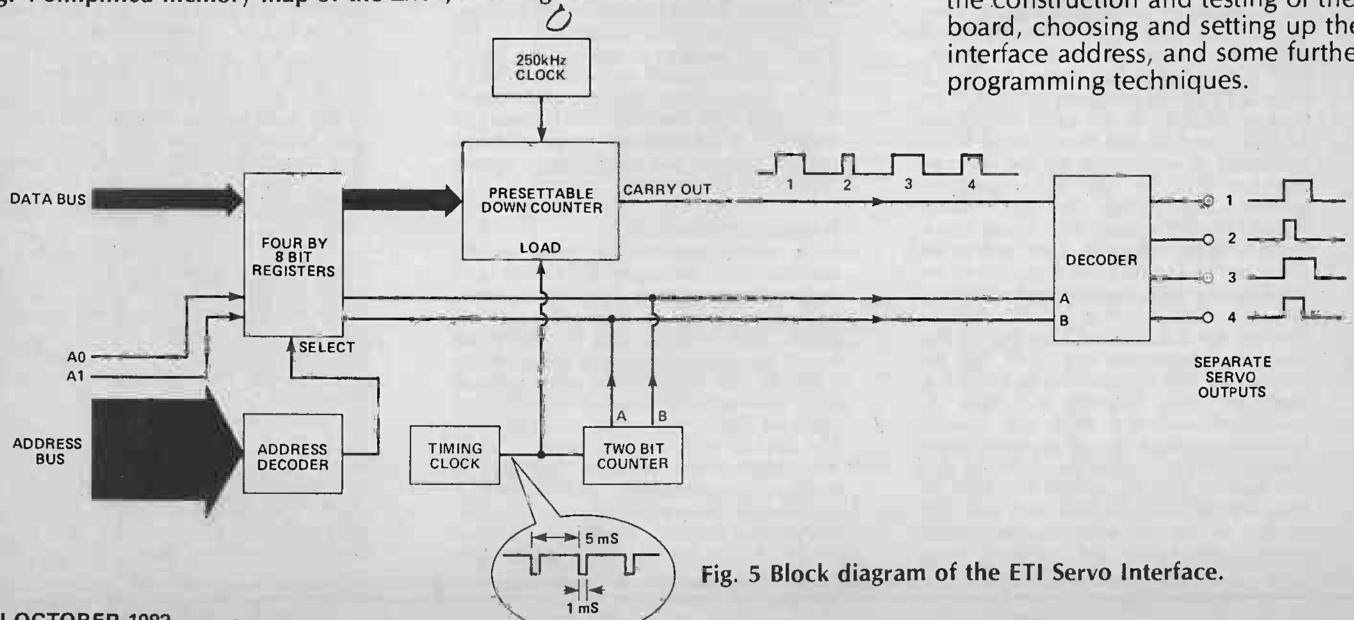


Fig. 5 Block diagram of the ETI Servo Interface.

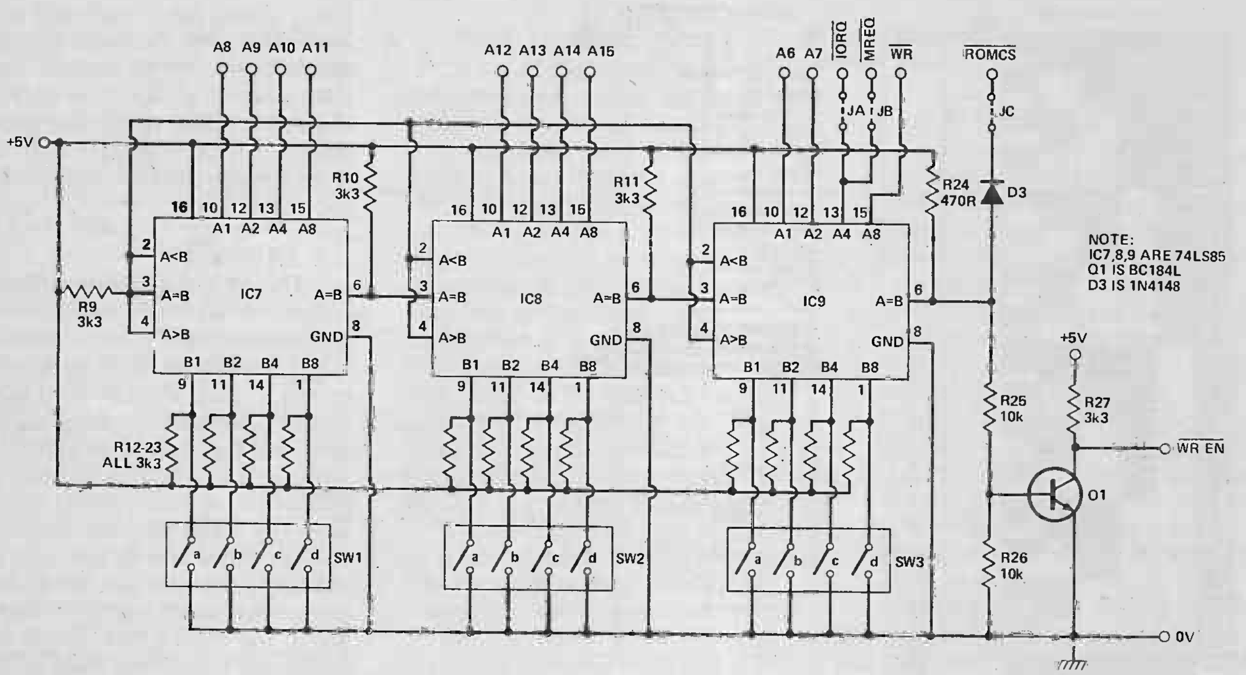


Fig. 6 Circuit diagram of the address decoder block.

HOW IT

ADDRESS DECODER

The block diagram of Fig. 5 gives an overall view of the servo interface system. The address decoder block can be considered as essentially separate from the main timing generator; its circuit is shown separately in Fig. 6. The address decoder merely allows the computer to send information to the timing generator. It detects when the computer outputs an address that corresponds to its own address, and then enables the servo position registers, so allowing them to be written to from the data bus. Certain control lines from the microprocessor are also gated into the address decoding so that the registers will not be enabled unless the computer is specifically writing to memory.

The decoder is built from a cascaded arrangement of identical four-bit TTL comparators, IC7, 8 and 9. Each comparator compares a binary word on the A inputs to that set up on the B inputs. If the two words are the same then the A = B output on pin 6 goes high so long as the A = B input is also high. The A = B inputs are connected to the A = B outputs of the preceding stages to give a total of 12 bits of comparison. The A inputs go directly to the most significant address bus bits and two control lines, while the B inputs are set by links or switches that tie the TTL inputs to ground when closed. Pull-up resistors R12–23 ensure a logic high input when these switches are open. One, two or all three of the comparator stages may be used on the PCB depending on the application. Resistors R10 and R11 ensure that the A = B inputs are kept high if the preceding stages are not used. For instance, an I/O mapped system on the Spectrum only requires IC9 and its associated switches. With the control line arrangement shown on the circuit diagram (SW3c,d must be closed to suit Z80 control signals) we are left with 10 lines for the address bits. Ten bits will decode a 16 bit address space into 64-byte blocks as the memory map diagram in Fig. 4 illustrates. This will usually be quite adequate since the switches can set this block anywhere in memory.

To summarise, when the address bits and control lines all correspond to the logic levels set on the switches then the A = B output goes high. This output is buffered and inverted by transistor Q1 to provide the WR ENABLE output for the timing generator. For Sinclair users it is also taken via D3 and a jumper link to the ROM chip select line (ROMCS). If this line is logic high the Sinclair 8K ROM is switched off; when IC9's output is logic low the diode allows the ROM to be selected by the ZX81 as necessary. The 8K ROM is not fully decoded on the ZX81, and 'echoes' of it appear across the 64K address space. It is often useful to place the interface at an address within one of these echoes and the jumper link achieves this by de-selecting the Sinclair ROM when the interface is addressed.

Jumper link Jb selects the MREQ control line for memory-mapped I/O on the ZX81, and jumper Ja selects the IORQ line for I/O-mapped output on the Spectrum. Since all the address and control line inputs are equivalent they could be arranged in an arbitrary order with any mix of address bits and control signals monitored for any logic pattern.

TIMING GENERATOR

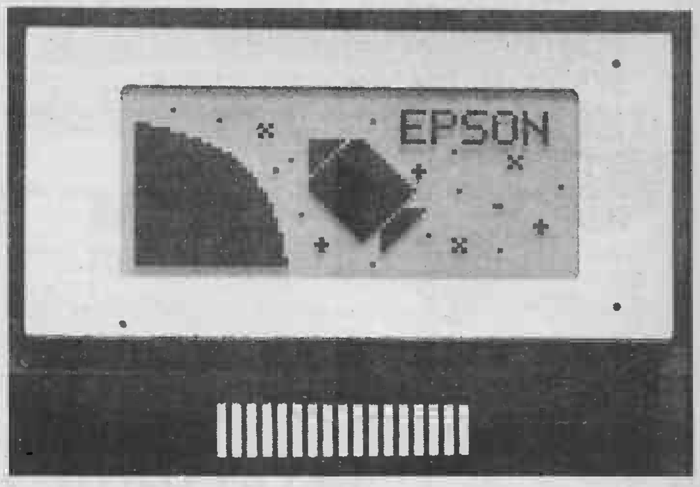
Each servo requires a pulse width variable from between 1 to 2mS and repeated every 20mS. The servo's position corresponds to the width of this pulse. Our system uses a seven bit binary number to represent this position which in turn controls the pulse generation. One position value is stored in an eight bit register for each servo channel. The data in these four registers is taken sequentially and used to generate a pulse of proportional width using a presettable down counter. The particular data for each channel is addressed by a two bit counter, which also routes the resultant pulse via a demultiplexer to the appropriate servo. An asymmetric clock which triggers the two bit channel counter also initiates the pulse generation. It has a full period of 5mS; thus all four servo channels are dealt with in 20mS to give the required frame rate. The timing diagram is shown in Fig. 8.

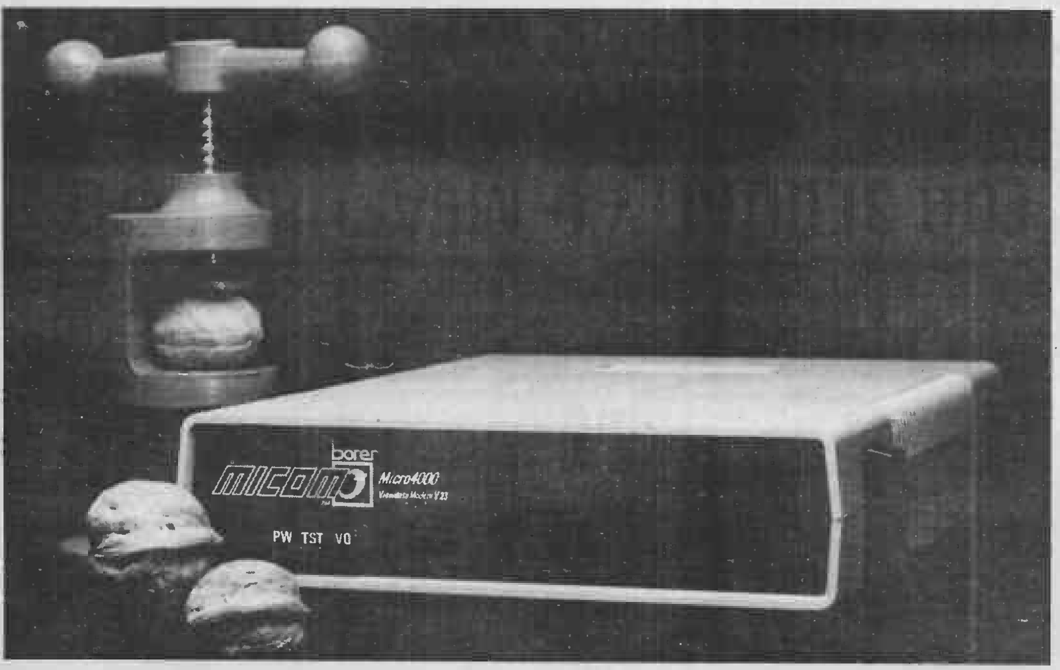
The detailed circuit diagram is shown in Fig. 7. The heart of this circuit is the eight bit binary down counter IC3, and its associated loading clock built around IC5b,c. Counter IC3 has eight preset inputs for determining the count start position. Input J0 is taken high for reasons of stability; we shall assume the other seven are set up to some binary value (this may be between 0 and 127). The clock input on pin 1 of IC3 is fed from a fast clock via an unusual form of AND gate (one half of decoder IC4 provides an AND function). The fast clock uses IC5a as a standard Schmitt trigger oscillator, its exact frequency being adjustable by PR1. The CARRY OUT signal on pin 14 of IC3 provides the servo pulse signals and is normally high during counting, but goes low when the count reaches zero. Since it's tied to one input of the AND gate, it disables the clock as zero is reached to prevent further counting. The CARRY OUT line is also sent to the decoder IC4 where the pulses are distributed to their corresponding servo channels.

CARRY OUT goes high again for another pulse when the ASYNC LOAD input on pin 9 is taken low. This also loads the binary value on the preset inputs into the counter, though counting will not commence until the LOAD input returns high. The LOAD pulses from the slow clock have an asymmetric duty cycle which remains low for a period of 1mS, thus determining the minimum servo pulse width. When the ASYNC LOAD returns high IC3 is released to count towards zero. CARRY OUT switches low after a time determined by the fast clock and the preset binary value,

Dotty Display

The new Epson liquid crystal graphics display module, designated ED-Y84320AT for reasons best known to the manufacturers, is now available from Norbain Displays Limited. Based on an 84 × 32 dot matrix within an effective viewing area of 76.3 mm × 33 mm, it is designed primarily for full graphics display applications but is also capable of reproducing alphanumeric characters. Featuring the recently developed twisted nematic (TN) type FEM liquid crystal, the displays have a high, 10 to 1 contrast giving greater character readability and a wide 60 degree left to right viewing angle. Each device has a built-in 80-byte data RAM, as well as a CMOS and TTL compatible LCD driver and controller which operate on a single 5 V power supply with a minimum power consumption of 0.6 mA. Full backlighting, allowing the displays to be used in the dark with ease, is achieved with the inclusion of an electro-luminescent panel. The displays have a life expectancy of approximately 50,000 hours. Applications include hand-held, point of sale and computer terminals, word processors, typewriters, instrument devices and all forms of telecommunications equipment. We imagine it's pretty useful for handheld games, too.





Nutty Photo

We have read this press release several times. We have scoured the photograph with a magnifying glass. We can safely state that there is absolutely no connection whatsoever between the Model 4023 Viewdata modem (for such it is) and walnuts. Or nutcrackers, come to that. Very strange. Putting our confusion aside, however, we'll tell you more about the modem. The modem is designed to meet the requirements of the Videotex application and requires only a single two-wire line for full-duplex asynchonous communication. The stand-alone version costs about £295 and offers an extremely compact design — up to 14 modems may be rack-mounted, occupying less than 9" of standard rack space. The 4023 Viewdata is available from Micom-Borer Ltd, 15 Cradock Road, Reading, Berks.

Shorts

- Good news for people with vibrating card frames — the new security card retainer from BICC-Vero Packaging Ltd fits into the card guide and stops your boards jiggling about.
- For computer programmers who feel that Forth is first, a version of this increasingly popular language has been written for the Sharp MZ-80B (operating under CP/M) by Kuma Computers, 11 York Road, Maidenhead, Berks. Cassette versions are available for the MZ-80K and MZ-80A.
- Course info 1: Slough College is offering a number of short courses in November aimed at computer professionals and business users, including such topics as 'CP/M Applications' and 'Personal Computing For Senior Managers'. Full details of the range of courses are available from Dr. Eva Huzan, Slough College, Wellington Street, Slough SL1 1YG (telephone Slough 34585).
- Harris Semiconductor (no relation) has introduced the industry's first 16 bit, monolithic, current output DAC, the rather obviously-named HI-DAC16. Applications will include process control, instrumentation, test instrumentation and digital audio systems.
- Dialling's gone digital in Germany with the installation of two new exchanges at Hamburg and Stade for long distance traffic. Installed by Siemens, the system handles the speech signals as digital data while they're in the exchange, and call routing is performed under program control.
- Roadrunner Electronics, whose wiring pen was reviewed in the June 82 issue of ETI, have published a new 28-page catalogue featuring a wide range of circuit board and enclosure accessories, as well as details of the whole Roadrunner wiring system. For a free copy write to Roadrunner at 116 Blackdown Rural Industries, Haste Hill, Haslemere, Surrey GU27 3AY.
- Course info 2: Three courses on the engineering aspects of microprocessors in industrial applications are being offered in Kent. For further details contact D.A. Chamberlain, Mid-Kent College of Higher and Further Education, Maidstone Road, Horsted, Chatham, Kent ME5 9UQ (telephone Medway 41001 ext. 247).
- Hurry, hurry, hurry — Gould Instruments of Roebuck Road, Hainault, Ilford, Essex are reducing the cost of their OS300 20 MHz dual trace oscilloscope from £295 to £265 for firm orders received before September 30th.
- Rapid Electronics, who now combine a greatly extended product range with their return-of-post service, have brought out a new catalogue. Copies can be obtained free with orders over £10 or by sending 45p to Rapid at Hil Farm Industrial Estate, Boxted, Colchester, Essex CO4 5RD.
- Course info 3: The Microprocessor Short Courses Unit, Dept. of Electronic and Electrical Enginering, University of Salford, Salford M5 4WT are offering new one-day courses in 6502 machine code programming and control/measurement applications. The courses are based on the popular PET computer and further information can be obtained from Mrs S.R. Hill (telephone 061-736 5843 ext. 248).
- Semiconductor Specialists of West Drayton are now stocking the new high efficiency green LEDs from GI Optoelectronics. The green devices are now comparable in brightness to high efficiency red LEDs.
- Lovers of brain-teasing adventure games will be glad to hear that a new cassette is available for the ZX81 (plus 16K RAM pack) which contains not one but three full-length adventures: Greedy Gulch, Magic Mountain and Pharaoh's Tomb. RRP is £5 including VAT from leading computer shops or by mail order from Phipps Associates, 99 East Street, Epsom, Surrey KT17 1EA.

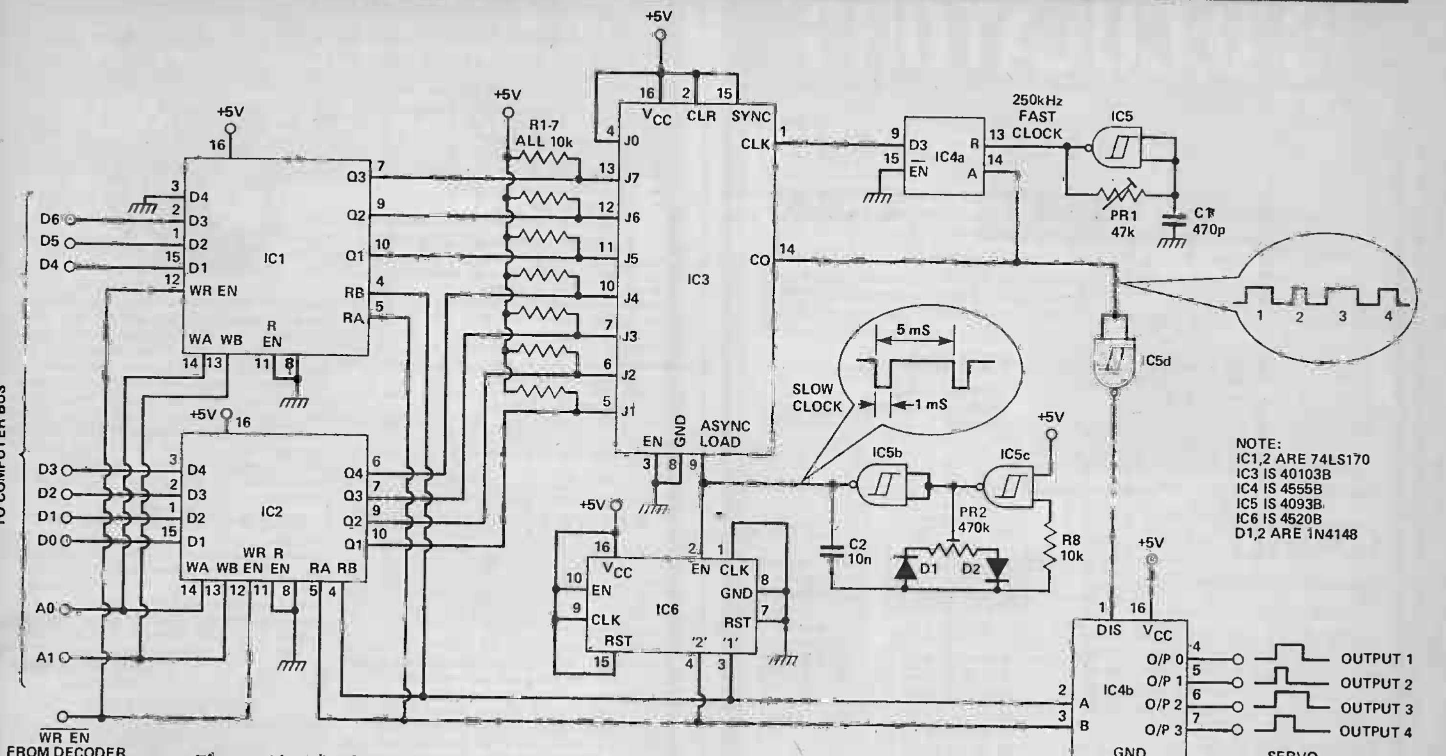


Fig. 7 Circuit diagram of the timing generator.

WORKS

thus terminating the pulse.

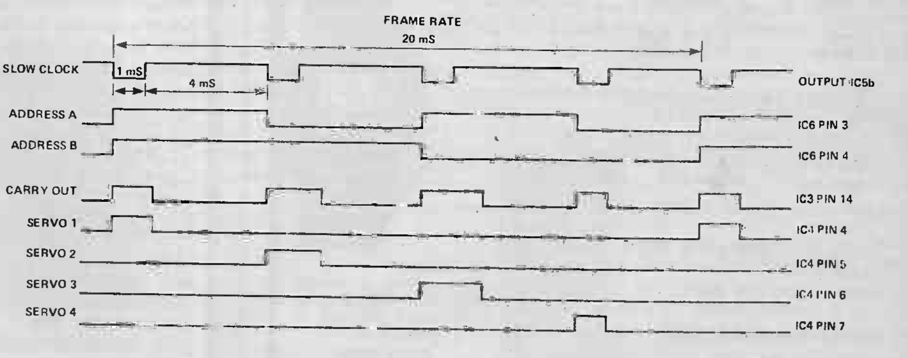
The allowable variation in servo pulse width for a given clock frequency, say 250kHz, will thus be determined by the binary value. At a value of zero it will be the minimum 1mS dictated by the LOAD pulse. When the binary input is 127 (taking into account the J0 preset input it's actually 255), the pulse width will be the maximum of 1mS + (255 × 4uS). The inset timing diagram of Fig. 8 illustrates the pulse generation. NAND gates IC5b and c (forming the slow clock) are configured as a standard CMOS astable with variable duty cycle. The overall frequency is set by C2 and the total value of the preset PR2; while D1 and D2 separate the charge and discharge paths through each arm of the preset to alter the duty-cycle independently of frequency (1mS high and 4mS low). The minimum pulse size for binary zero can thus be altered from 1mS by adjusting the duty cycle with PR2. The maximum pulse at binary 127 depends on the fast clock frequency and may be adjusted with PR1.

The two-bit binary counter formed from IC6 addresses the servo whose particular pulse is being generated at any given moment. IC6 is a dual four-bit counter (the 4520). The first two bits of one counter, pins 3 and 4, are used as the A and B addresses for the pulse selection. Counting is clocked on the negative-going edge of the load pulse by using the clock enable input on pin 2 and tying the clock input to ground. These repeating address states perform two functions; they select one of four registers containing the servo position data word, and they also select one path of the demultiplexer IC4 to route the pulse to its associated servo. Thus four servo timing slots occur in the 20mS frame period.

IC1 and 2 are the servo position data registers (74LS170s). Each IC contains four four-bit words of memory and they are simply connected in parallel to give four seven-bit words. These registers are special in that they contain separate read and write address decoding for each word, allowing simultaneous reading and writing. The data inputs (on pins 15, 1, 2 and 3 and connected to the computer's data bus) are also separate from the data outputs (on pins 10, 9, 7, and 6) that are sent to the timing generator. Thus the timing generator can read the four registers in turn, by scanning through the read addresses on pins 4 and 5, while at the same time the computer can address any register via the write addresses on pins 13 and 14, and write new data into this location with a 'memory write' instruction. The write addresses are wired to the computer's least significant address bus bits, so the registers will simply appear as consecutive memory locations ('write only' memory). Direct memory mapping is thus achieved between the computer and the servo positioning.

The READ ENABLE input on pin 11 (active low) is grounded to allow permanent read access for the timing generator. The WRITE ENABLE input on pin 12 is driven from the address decoder output. Thus the registers will only 'see' the computer's data bus when the interface is specifically addressed by the microprocessor for a memory write operation.

Capacitors C3, C4 and C5 are included across the supply lines providing the requisite TTL supply decoupling.



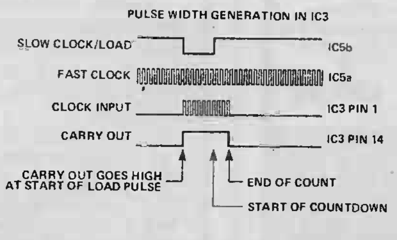
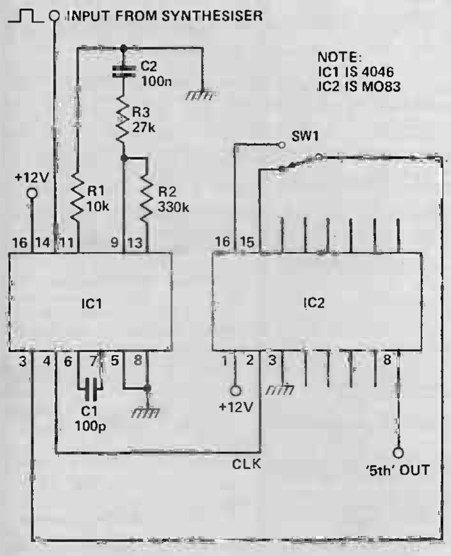


Fig. 8 Timing diagram for the servo interface.

Next month we'll be publishing the component overlay, Parts list and some sample BASIC programs.

TECH TIPS

MINIMUM PAYMENT £20



Enriching Synthesiser Sounds

H. Duncan, Aberdeen

When working with synthesisers I have found that a much richer sound can be obtained if a second VCO is tuned to a fifth above the first. This can cause problems if quick patch changes are required since the second VCO will have to be retuned. The circuit given here overcomes this problem cheaply, leaves the second VCO free and also lends itself to other interesting applications.

IC1 is wired as a standard phase-locked loop, with R1, C1 setting the maximum operating frequency and R2, R3, C2 feeding the error voltage to the 4046 VCO. The output of the 4046 is used to clock IC2, a top octave divider, which divides the input by a series of integers to produce semitones. One of the two 'C' outputs is sent back to the PLL via SW1.

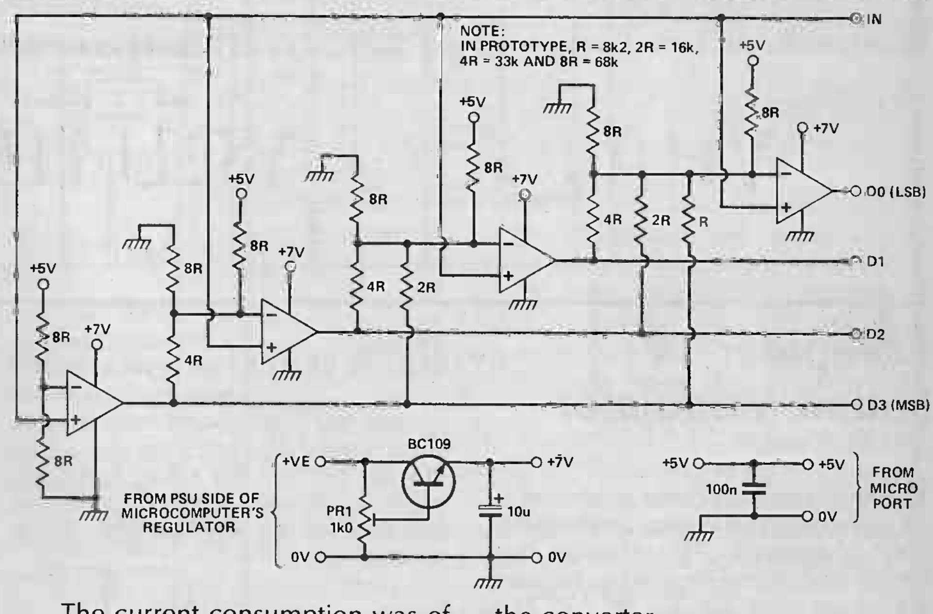
The circuit will now track accurately any square pulse of suitable level, for example from a CEM3340, and produce any semitone in an octave starting from the input frequency or the one above. The output is, of course, only a square wave, but by suitable shaping any waveform may be derived. Clearly the circuit is open to many modifications; for example, if the top octave divider is replaced by a 4024 divider, with suitable decoding and filtering harmonics could be obtained, making any sound possible!

Four Bit Analogue-to-Digital Converter

P. A. Barber, Manchester

This converter was designed to be a cheap and relatively simple alternative to ADCs made from counters/ramps. It uses standard op-amps as voltage comparators, one for each bit. Each comparator is fed with the input signal and a reference voltage that depends on the states of the more significant bits. For example the threshold of bit D2 will be either $\frac{1}{4}$ or $\frac{3}{4}$ of the input range (in this case 5V) depending on whether the MSB (D2) is set to a 1 or a 0; similarly the reference voltage for the D1 comparator will be set to $\frac{7}{8}$, $\frac{5}{8}$, $\frac{3}{8}$, or $\frac{1}{8}$ of 5V for the values of D3 and D2 set to 11, 10, 01, 00 respectively.

In order for the D-to-A parts of the circuit (all the resistors) to supply these voltages, the outputs of the comparators must swing from 0 V to 5 V which few op-amp packages can manage. In the prototype I used ordinary 3140 op-amps with an extra supply rail of a few volts above 5 V.



The current consumption was of the order of a few milliamps. The frequency response was difficult to measure on the limited equipment available but a reasonable trace was produced by reading the unit with a machine code routine on a ZX81 with an expansion port while music from a tape recorder was played into the converter.

Although the unit was made as a four bit converter any number of bits could be connected giving better resolution at the expense of operating speed and greater cost (the number of resistors required varies as $2b + b(b-1)/2$ where b is the number of bits).

Tech-Tips is an ideas forum and is not aimed at the beginner. We regret we cannot answer queries on these items. ITI is prepared to consider circuits or ideas submitted by readers for this page. All items used will be paid for at a competitive rate.
Drawings should be as clear as possible and the text should be typed. Text and drawings must be on separate sheets. Circuits must not be subject to copyright. Items for consideration should be sent to ETI TECH-TIPS, Electronics Today International, 145 Charing Cross Road, London WC2H 0EE.

240 V To 120 V Converter For Resistive Loads

M. Greenfield, Leeds

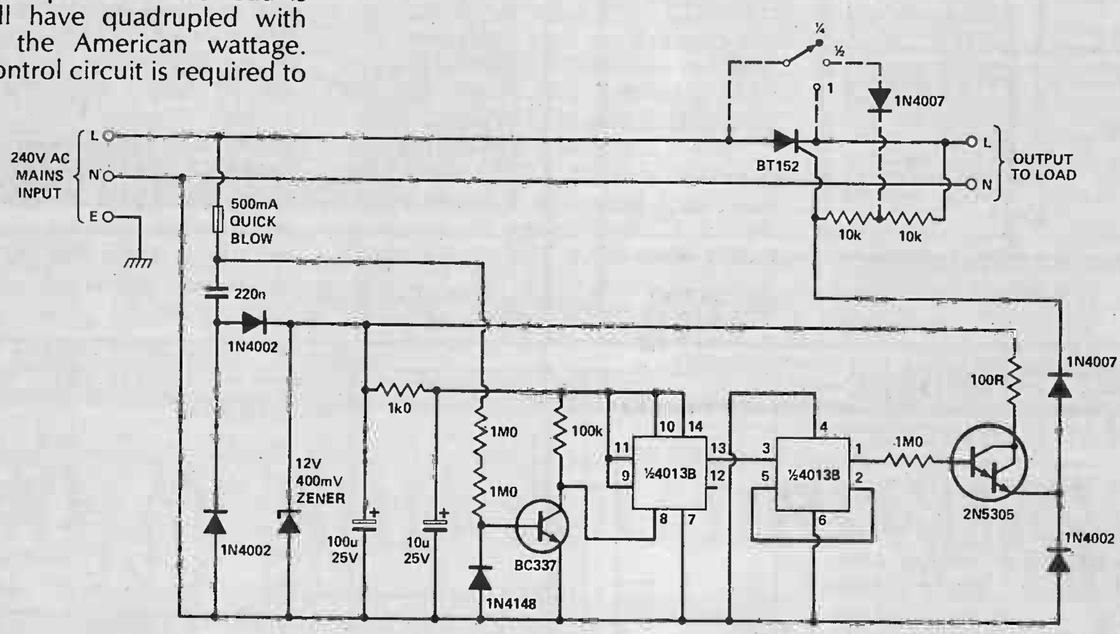
A friend visiting the USA has brought back with him a percolator and an electric stewing pan, both for 110 V operation, rated at 600 W and 1.2 kW respectively. He was under the impression that a small transformer would do but this, of course, was not practical and the solution had to be electronic.

Since the power in the load is V^2/R it will have quadrupled with respect to the American wattage. Thus the control circuit is required to produce one half-cycle in every two mains cycles, using a thyristor. Switching at the zero-crossing point of the mains cycle eliminates the need for RFI suppression.

The circuit consists of a 12 V 50 Hz square wave shaper, this being a BC337 transistor followed by one flip-flop within a 4013 CMOS IC. The signal is then divided by two, using the other flip-flop of the IC, producing a 25 Hz square wave which is further buffered by a 2N5305 Darlington transistor. The latter drives the thyristor, a BT152. Note the two 1M0 and two 10k resistors in series; this combination overcomes the resistor voltage rating limitation.

Power to the logic circuit is provided by means of a diode pump. The 220n pump series capacitor is effectively connected across the mains and it should have a corresponding voltage rating (250 V AC suppression capacitor).

The circuit was tried with resistive loads of up to 1.5 kW. A further application would be to control resistive loads rated for 240 V AC operation (eg a 1 kW bar heater) to full, half or quarter power. This can be done using the additions shown in dotted lines.



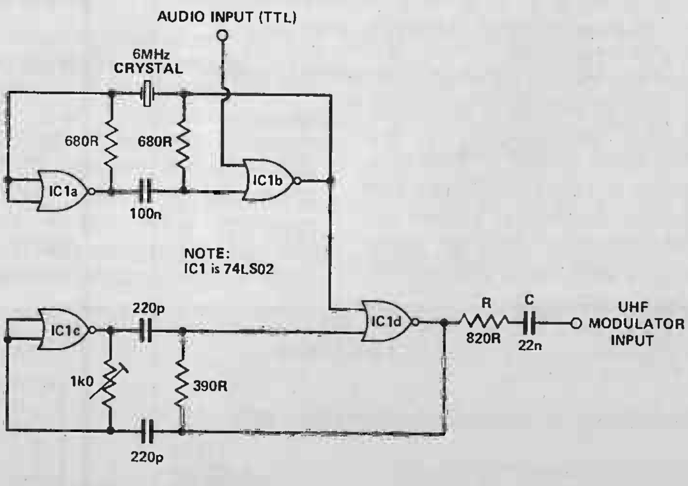
Computer TV Sound Modulator

J. Wike, Cardiff

When a computer that generates a square wave type audio signal is used with a domestic TV receiver, this simple circuit can be used to transfer the sound onto the TV. All 625 line transmissions in the UK use a frequency-modulated sound carrier spaced at 6 MHz from the vision carrier. In the receiver the two carriers are mixed to give a 6 MHz sound 'sub-carrier' superimposed on the vision signal. This is known as the inter-carrier system. It is possible to insert an external sound sub-carrier onto the video signal and this will be correctly detected by the receiver.

The circuit shown is a very simple frequency modulator which will switch between two frequencies depending on the level at the TTL input. The output is mixed into the video input to the computer's UHF modulator via the resistor-capacitor network. Quite a high level of sound carrier (approximately 500 mV pk–pk) has been found necessary to overcome video buzz on the audio output, but on the other hand too high a sound carrier produces interference on the picture. Some experimentation with the resistor value is therefore required to get the best compromise.

When the circuit is connected up the frequency of the variable oscillator should be adjusted to give the loudest undistorted output from the TV loudspeaker.

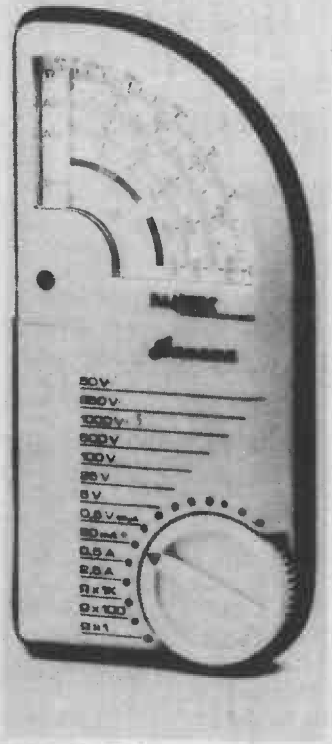


SET VARIABLE OSCILLATOR FREQUENCY TO 6.05MHz OR 5.95MHz

ETI

Going Bananas

The slightly silly season is upon us. The analogue multimeter in the photograph is somewhat untraditional in design, having an odd shape and bright yellow colour which gives it its name — the Banana 1. Obviously the designers have taken a lead from those well-known fruit-lovers, the microcomputing manufacturers. Designed for (clumsy?) engineers in rugged environments, the Banana will withstand a 2 m fall, the range selector can be operated with one finger and the probes are permanently connected to prevent loss or insertion errors. The meter has three AC voltage ranges (up to 750 V), five DC voltage ranges (up to 500 V), four DC current ranges (up to 2A5), and three resistance ranges (2M0 maximum). There's also a continuity tester for resistances under 30 ohms and a visual battery check. The Banana 1 costs £17.95 plus VAT (that's for one only, not a bunch) and is available from Solent Component Supplies, Warren Avenue, Milton, Portsmouth PO4 8PY.



New Oldies

For a real trip down memory lane there's no better publication than the latest catalogue from the Vintage Wireless Company. This amazing tome contains 92 pages of truly antique electronics — a glance through the index reveals such entries as ebonite, gramophone needles, condensors, output transformers and valves. It's all very weird and wonderful to us children of the transistor age, and worth getting hold of if only for the period advertisments (Ekco three-valve Consolette Receiver, only 15 Guineas or easy payments over one or two years). Lovely stuff. The office and showroom of the Vintage Wireless Company is at 64 Broad Street, Staple Hill, Bristol, BS16 5NL.

Low Cost, Low Current LCD

By which we mean £19.95 plus VAT (one off price) and 150uA. The DPM 05 is the latest LCD panel meter to be introduced by Lascar Electronics of Oakland House, Reeves Way, South Woodham Ferrers, Chelmsford, Essex CM3 5XQ. The price includes mounting bezel and hardware; battery life is several months continuous use from a PP3 and a 'LO BAT' warning indicates when there's 20% life left. All the usual features are there — autopolarity, autozero, bandgap voltage reference, programmable decimal points and an FSD of 200mV — so we'd feel safe in betting our hard-earned pennies on which DVM chip they've used (see Notebook for July). The display height is 0.5".

Stand For Anything

Wilmslow Audio are famous for their excellent range of loudspeakers; now their associate company, Riverside Wood Products, have produced a range of hi-fi speaker stands. The dB Speaker Supports (odd name, but no matter) come in small, medium and large models and African Walnut (solid, not veneer), black or plain finishes. The VAT-inclusive prices are £33, £34 and £36.80 for walnut or black stands in the three sizes. The dB Speaker Supports are available from the usual hi-fi outlets or by mail order from Wilmslow Audio, 35/39 Church Street, Wilmslow, Cheshire SK9 1AS.

Eagle's Cat

Electronics company Eagle International have issued a new, colour, 84 page catalogue to coincide with the launch of over eighty new products. These include a new series of public address amplifiers, loudspeakers and microphones as well as additions to their intercom, test instrument and security detection equipment. New consumer models include a component stereo system, mini 'hip' radio with headphones, alarm clock radios and ICE equipment. Copies of the catalogue are available free of charge, on request to Eagle International, Precision Centre, Heather Park Drive, Wembley, Middlesex HA0 1SAU.

DESIGNER'S NOTEBOOK

Nowadays, measurement usually means digital measurement. Tim Orr concludes his look at instrumentation techniques with details of how to use DVM chips to get all the basic ranges of a multimeter, and more!

The following sections should give you enough information to go ahead and design your own digital multimeter, customised to give exactly the ranges and features you find most useful. We also look at techniques for measuring temperature and dealing with very small signals.

Dedicated DVMs

Intersil make a pair of DVM chips (Fig. 1, Fig. 2) that make life very easy if you want to measure and display a voltage. These chips are the ICL7106 and the 7107 and they seem to have become an industry standard. The first device is an LCD version and the whole lot consumes a mere 1 mA when running; it can run from a single 9 V (PP3) battery. The second device uses an LED display. The display may consume up to 100 mA, making battery operation a problem. Several companies make modules that contain both the DVM chip and a display. All you need to do is power it up and send it a voltage. It is, in fact, an 'instant' DVM module — no talent required.

The Intersil chips have a differential input with an input current of only 10 pA maximum, 1 pA typical. The devices have an auto zero facility so that they automatically cancel out any offset voltages at the input. The input sensitivity is 200 mV, but by connecting various amplifers, attenuators, RMS and dB converters and filters to the DVM chip a wide range of signal measurements can be performed.

Measuring Voltage . . .

Figure 2 shows the standard 1 megohm input impedance decade attenuator that is used in most digital multimeters. The very high input impedance of the 7106/7 produces negligble loading of the attenuator network. Figure 4 shows a standard four decade DC voltmeter circuit. If voltages below 200 mV are to be investigated then a preamplifier with low offset and drift characteristics is needed. The resistors used in the attentuator are standard E96 values and can be obtained with a 0.5% tolerance.

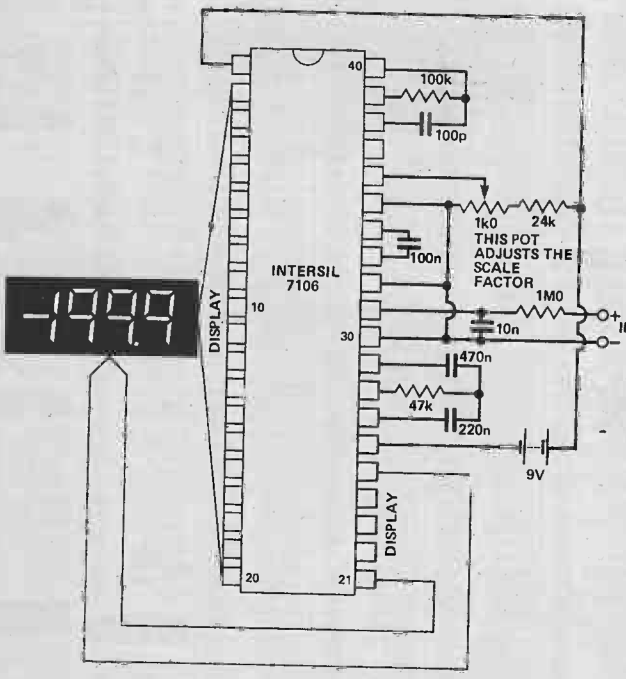


Fig. 1 The Intersil ICL7106 with liquid crystal display.

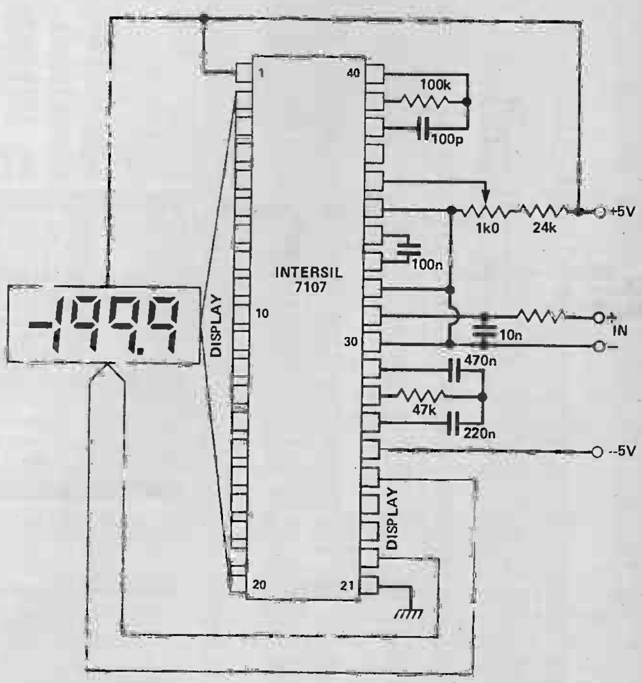


Fig. 2 The Intersil ICL7107 with LED display.

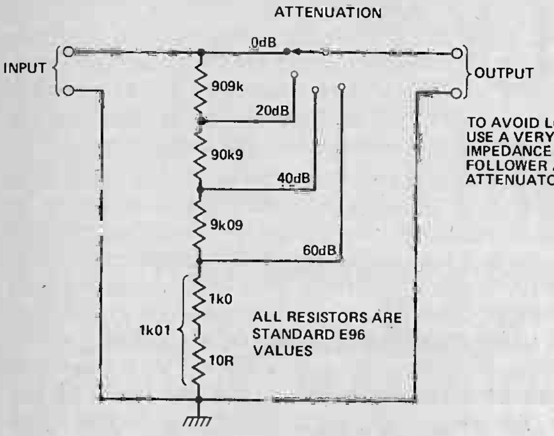


Fig. 3 A 20 dB step attenuator.

. . . Current . . .

Figure 5 is a current meter circuit; the current is made to pass through shunt resistors. This sets up a DC voltage (no more than 200 mV) which is measured by the

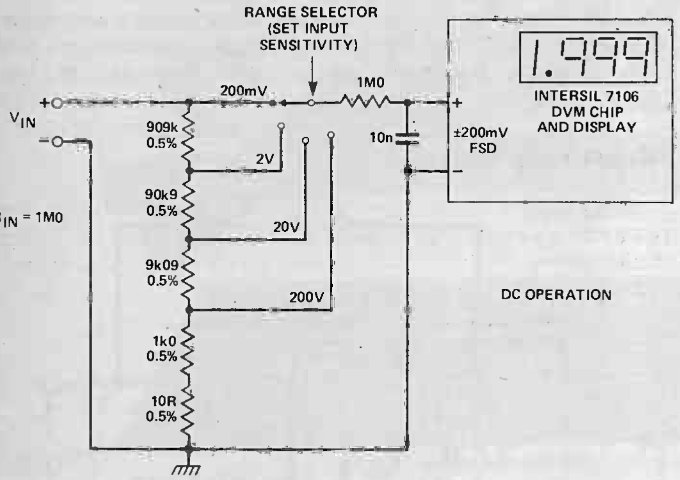


Fig. 4 A decade 3½ digit digital voltmeter.

DVM chip. The input is protected by a diode bridge that pops the fuse when the input voltage exceeds 1V8 (three diode voltages) and the current exceeds 3 A. If you could pass unlimited current through the resistor network then you would probably end up with a fire!

. . . And Ohms

Figure 6 is an ohmmeter circuit. The 741 op-amp generates a precision and stable −1V2 DC reference voltage which causes a fixed current to flow into the virtual earth input of the LF355; the current will be 10 mA using the 120 ohm resistor, 1 mA using the 1k2 resistor and so on. This fixed current also flows through the test resistor which is the feedback route for the LF355 and in doing so sets up a voltage that in linearly proportional to the value of the test resistor. At 'full-scale-deflection' the output of

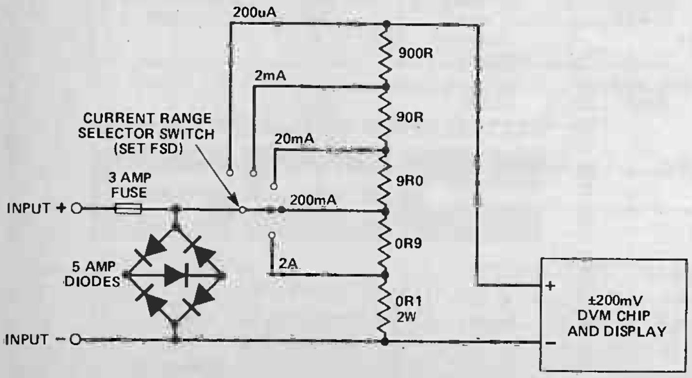


Fig. 5 A five decade DC current meter.

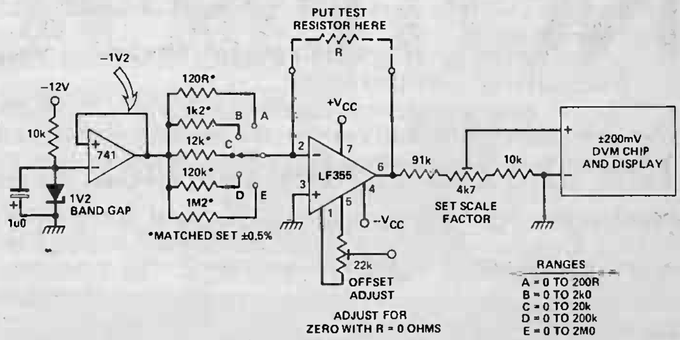


Fig. 6 A five decade ohmmeter.

the LF355 is 2 V which is attenuated to 200 mV; this voltage is then fed to the DVM chip. The LF355 is a JFET op-amp which has a small input current and offset voltage and low temperature drift characteristics. Even so it is bet-

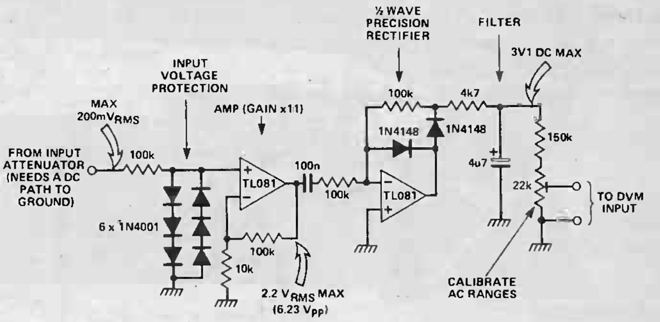


Fig. 7 An AC voltage and current converter. This is only accurate for sine waves.

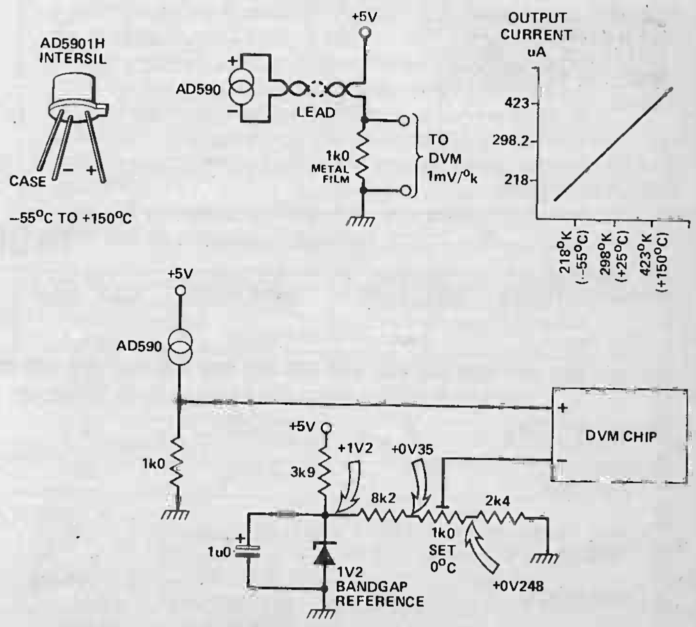


Fig. 8 Reading degrees Kelvin (top) and Centrigrade (bottom).

ter to run the output at 2 V and then attenuate it to 200 V, because this also attenuates any residual offsets and other errors.

Figure 7 shows a simple AC converter circuit that is a cheaper alternative to the RMS to DC converter published last month. It can be used to measure V RMS and I RMS for a sine wave input. The circuit is a high impedance buffer/amplifier with a half-wave precision rectifier and smoothing circuit.

Measuring Temperature

Intersil makes a device called the AD5901H which converts temperature into current; the device generates an output current of 1uA per degree Kelvin. Absolute zero in degrees Kelvin is −273.2°C and so 0°C = 273.2°K. If this temperature-dependent current is dumped into a 1k0 resistor then the voltage across the resistor will increase by 1 mV per degree K (or C) — see Fig. 8. The operating range of the device is −55°C to +150°C which will generate a voltage change of 205 mV across the 1k0 resistor. This can easily be displayed on the ±200 mV range of the DVM chip. The sensor plus the DVM and display make a very simple and compact battery operated digital thermometer.

Amplifying Small Signals

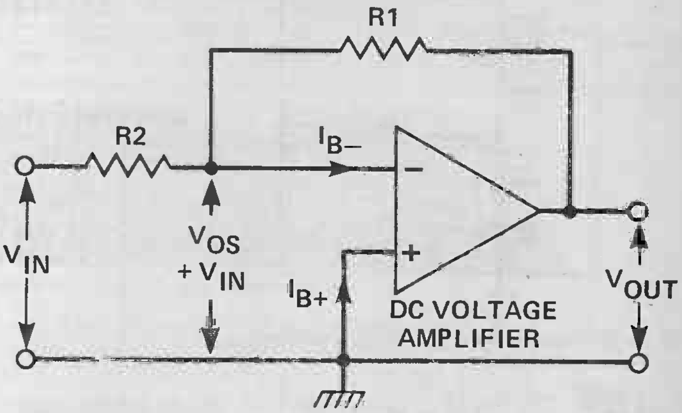
Often you need to amplify very small DC voltages. The output from strain gauges or thermocouples is very small, often below 1 mV. This would hardly cause any movement in a 200 mV DVM chip. However, an amplifier that will operate in the sub-millivolt area is quite difficult to make with any accuracy. For example, a 741 op-amp might have an input offset of 2mV (Table 2). this error is actually bigger than the voltage we are measuring!

There are four main sources of error. I_B, the input bias current, has to flow through R1 and R2 and in doing so upsets the gain equation. Note that I_{B-} is not exactly the same value as I_{B+}! V_{OS} is the input offset voltage which represents a DC input imbalance. This also upsets the gain equation. Furthermore, V_{OS} has a temperature coefficient V_{OSTC} which is the maximum change in V_{OS} per degree C. So the amplifier will drift with temperature. V_n is the input noise voltage, which is multiplied by the fixed gain on the amplifier. If the noise is similar in amplitude to the input voltage then you are going to get noisy readings. Finally, the input offset voltage drifts with time — it ages! Very few manufacturers provide information regarding this parameter.

The selection chart (Table 2) shows a range of in strumentation and ordinary op-amp error parameters. The way to overcome these errors is to use a suitable op-amp rather than to use a low performance part and to try and cancel out all the drifts and offsets. The details given in the chart only show some of the many parameters that manufacturers specify. Devices are often graded into several performance categories, so if you want to design high quality amplifiers then refer to the manufacturers' detailed data.

TABLE 1

DEVICE	E IN uV RMS (AVERAGE OF SEVERAL SAMPLES)	NOISE LEVEL RELATIVE TO NE5534 IN dBs
NE5534 (SIGNETICS)	0.59	0
RC4136 (RAYTHEON)	0.87	+3.4
RC4739 (RAYTHEON)	1.00	+4.6
RC4558 (RAYTHEON)	1.05	+5.0
TL081 (TEXAS)	1.61	+8.7
741 (VARIOUS MANUFACTURERS)	1.72	+9.3



$$V_{OUT} = \left(V_{IN} \times \frac{R1}{R2}\right) + \text{ERRORS}$$

Fig. 9 Choosing a precision op-amp. Table 1 (left) gives some typical noise results, Table 2 (below) shows typical values for the errors shown in the above diagram.

TABLE 2

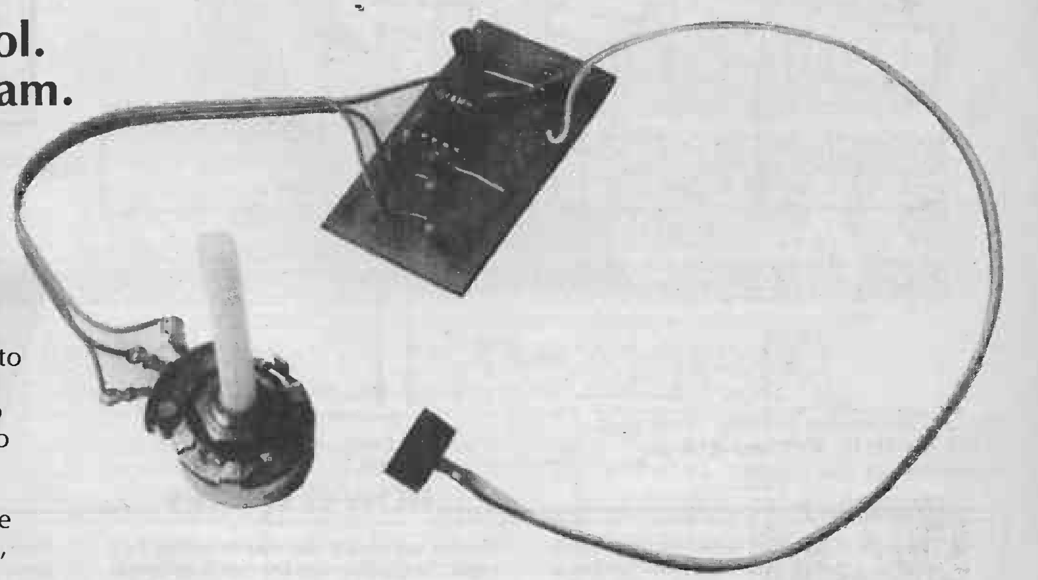
DEVICE MANUFACTURER	LM363 NAT. SEMI	ICL7650 INTERSIL	LF355 NAT. SEMI	TL081 TEXAS	741 —	725 —	OP-27A/E PMI
I_B	2 nA	10 pA	30 pA	5 pA	80 nA	42 nA	10 nA
V_{OS}(uV)	30	1	2000	5000	2000	500	10
V_{OSTC} (uV/°C)	2	0.05	5	20	2	0.6	0.2
NOISE (V_n) (nV/√Hz)	12	2 uV_{pp}	20	20	14	9	3
LONG TERM DRIFT	—	100 nV/month	—	—	—	—	200 nV/month
COMMENTS	Av = 100	Chopper stabilised op-amp	JFET op-amp	JFET op-amp	Bipolar op-amp	Instrumentation op-amp	Ultra-low noise precision op-amp

ETI

FREE PCB PROJECTS

HEAT LIGHT CONTROLLER

In the dark or frozen out? Don't be with the ETI switching unit, designed for porch lights or thermostatic control. Design by Andy Elam. Development by Dave Bradshaw.



One of the main uses of electronics is in control systems. The design we describe here can be used either to control a porch light, so that it comes on when it gets dark, or to act as a thermostat. It's possible to adapt this circuit to other uses as well, provided you have a transducer that varies its resistance with the controlled parameter. So, for example, you could use the same circuit with a level sensor and a relay-controlled valve to keep the water level constant in a storage tank.

If the circuit is used as a thermostat, the transducer should be a thermistor with a negative temperature coefficient and a range of operation covering the temperature you want to control. The values chosen for the circuit should work with most thermistors, but if you have problems you can alter the value of R2 to compensate — it should be within a factor of three or so of the thermistor resistance at control temperature.

How heavy a load can be switched depends on the relay contacts; if you don't use a relay that's up to the job it won't last very long. It is particularly important to use a suitable relay if you want to control a mains-powered appliance. And take great care to ensure that the electronics is well separated from the mains. Using a more meaty transistor for Q1 (and adjusting R5 and R6 for a correspondingly higher base current) will make it possible to drive a fairly hefty relay, though it must have a 12 V coil.

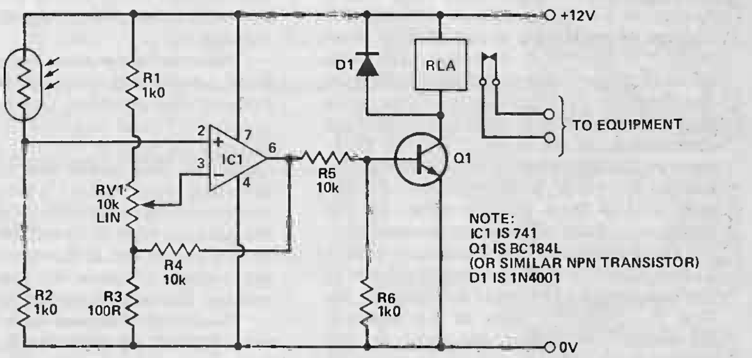


Fig. 1 Circuit diagram of porch light controller or thermostat.

Construction

Assembly of the components on to the PCB should be straightforward provided the overlay shown is carefully followed. We suggest using Vero pins for the wiring connections and these should be attached first. Next solder in the resistors, then all the other components. Be sure to get the connections of D1 the correct way around and note that the connections of Q1 will vary depending on what type of transistor you use — it may be necessary to bend the leads to get the transistor to fit if you don't use the BC184L we specify.

Once you've built the circuit, you can check it's working correctly by connecting the power and adjusting RV1. If it is working, the relay will switch on and off as you move the wiper of RV1 from one end of the track to the other.

Next install the transducer in position, and then set RV1 so that the relay energises at the desired light level or temperature. However, the LDR shouldn't be illuminated by the porch light it's controlling, or you'll get oscillation which isn't the effect we're looking for!